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# Journal of the New England Water Works Association

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March, June, September and December

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NEW ENGLAND WATER WORKS ASSOCIATION
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# New England Water Works Association
## 1958-1959

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THE Association was organized in Boston, Mass., on June 21, 1882, with the object of providing its members with means of social intercourse and for the exchange of knowledge pertaining to the construction and management of water works. From an original membership of only TWENTY-SEVEN, its growth has prospered until now it includes the names of over 1000 men. Its membership is divided into six classes, viz.:

*A Member* shall be an officer or employee of a public or private water works, an engineer, chemist or other person qualified to aid or interested in the advancement of knowledge relative to water works.

*An Honorary Member* shall be a person of acknowledged eminence in some branch of water supply or of engineering.

*A Junior* shall be not less than eighteen years nor more than twenty-five years of age, a student or connected with water supply work.

*An Associate* shall be either a person, firm or corporation engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works.

*A Corporate Member* shall be either a Water Board, Commission, Company or Municipal Corporation.

The initiation fees and annual dues are as follows:

| | *Initiation Fees* | | *Annual Dues* |
|---|---|---|---|
| Members | $ 5.00 | Members | $ 5.00 |
| Juniors | 1.00 | Juniors | 3.00 |
| Associates | 10.00 | Associate | 25.00 |
| Corporate Members | 10.00 | Corporate Members | 15.00 |

This Association has at least eight regular meetings each year, of which five are held in Boston, one in northern New England, one in southern New England, and one, the annual convention, held in September or October on such date as the Executive Committee may designate.

Thousands of tons of timber will be unleashed on the waters of the river. Similarly, our explosive surge of population is bearing down on already overburdened water works facilities in many communities.

New pipelines are essential; but only pipe of sustained high carrying capacity can meet greater demands with constant, predictable volume. That's why efficiency and economy dictate the use of LOCK JOINT CONCRETE PRESSURE PIPE for water supply and distribution lines. Its first low cost, ease of installation, long life, negligible maintenance and permanent high carrying capacity represent immediate and long term economies.

To bolster your water system against the shock of our yearly 3,000,000 increase in population, specify LOCK JOINT CONCRETE PRESSURE PIPE for complete dependability and over-all economy.

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Sales Offices: Chicago, Ill. • Columbia, S. C. • Denver, Col. • Detroit, Mich. • Hartford, Conn. • Kansas City, Mo. • Perryman, Md.

Pressure • Water • Sewer • REINFORCED CONCRETE PIPE • Culvert • Subaqueous

Reader's

## Oh, what will you do without water?

America is using 167 million gallons of water a minute!

Demand increases by the hour. By the time today's toddlers are grown, we'll need *twice* as much water.

Where will it all come from? Will you have enough? You'll find the answer below . . .

### Now, what can you do about water?

This free booklet, "*WATER—make sure you'll always have plenty,*" tells how to learn if you're running short, what to do if you are. Write Cast Iron Pipe Research Assn., Prudential Plaza, Chicago 1, Ill.

*Printed in your interest by the makers of America's greatest water carrier . . .*

CAST IRON PIPE

# New Ad Campaign in Reader's Digest Dramatizes America's Water Problem

*Cast Iron Pipe Research Association promotes better understanding of water supply and distribution problems*

**Offers Informative Booklet for Step-by-Step Action at the Local Level**

Here's help for you and everyone else directly concerned with the supply, treatment and distribution of water—help that will acquaint the people in your town with the vital importance of this growing problem.

On the opposite page you see the first in a series of advertisements, this one appearing in February *Reader's Digest*. Placed by the Cast Iron Pipe Research Association, these striking advertisements point out to Mr. and Mrs. America how much we depend on a good water system and why we can no longer take it for granted.

Similar advertising will appear regularly this year in *U. S. News & World Report, Nation's Business, Better Homes & Gardens, American Home* and *Sunset* magazines to carry this public service message to millions of community leaders and homeowners.

***Free Local Plan-of-Action Booklet***

These ads offer a free booklet telling about the water problem. It shows how responsible citizens can acquaint themselves with the needs of their community. It also gives a step-by-step outline of action, telling how they can help their officials extend and improve the local water system through more adequate rate structures or financing.

We'll be happy to send you a free copy of this new booklet. Write to Thos. Wolfe, Managing Director, Cast Iron Pipe Research Association, 3440 Prudential Plaza, Chicago 1, Ill.

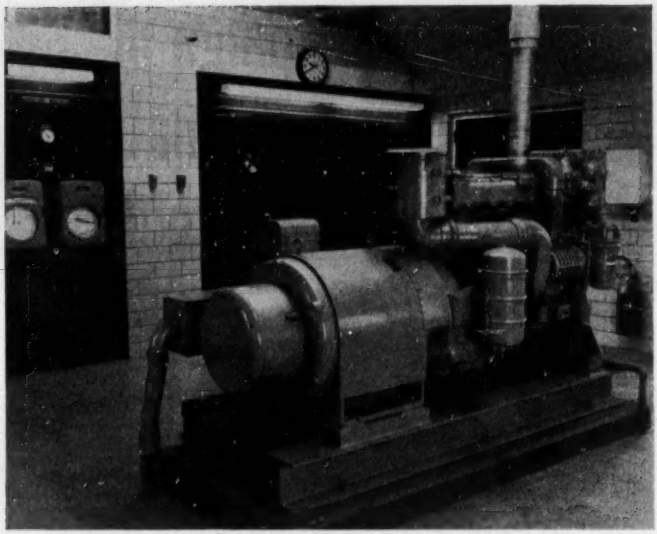
***Three reasons why cast iron pipe is America's greatest water carrier:***

1. More miles of underground cast iron water mains are now in use than of all other kinds of pipe combined.

2. More miles of cast iron water mains are now being purchased and laid than of any other kind of pipe.

3. Impartial surveys prove that today's water utility officials and consulting engineers prefer cast iron pipe for underground water distribution by an overwhelming majority.

**CAST IRON PIPE**



**Diesel Generator Set**
**Brunswick and Topsham Water District**
**Brunswick, Maine**

This 125 KW CUMMINS Diesel Generator Set provides stand-by power at Taylor Farm Supply, Brunswick and Topsham Water District. The generator set is specially designed to start a 100 HP pump motor.

Camp, Dresser and McKee of Boston, Massachusetts, were the engineers for this unusual application of diesel power.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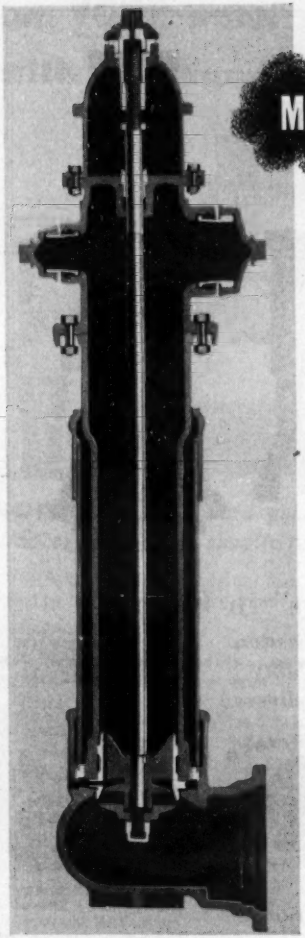

# MATHEWS HYDRANTS

**The Mathews Modernized Hydrant Supplies the 4 Fundamental Requirements for Effective Community Protection**

***and many other quality features, too***

- Replaceable barrel for maximum efficiency—quickly replaced in case of accident without excavating
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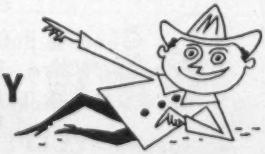
- Operating thread, protected by stuffing box plate, operates free of rust, sediment and ice

Also . . . Nozzle sections supplied with hose or pumper outlets as specified • Operating thread cannot be bent • Compression-type main valve prevents broken Mathews from leaking • Nozzle level can be raised or lowered without excavating • Bell, mechanical-joint, or flange-type pipe connections • Conventional or "O" ring packings



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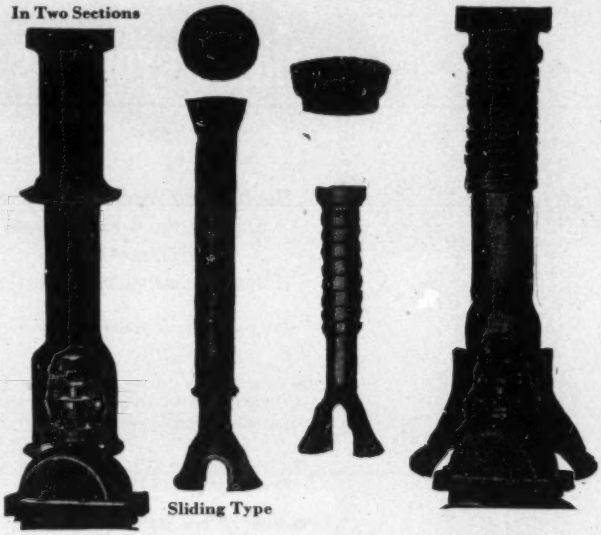
## R. D. WOOD COMPANY

**Public Ledger Building, Independence Square, Philadelphia 5, Pa.**

Manufacturers of "Sand-Spun" Pipe (centrifugally cast in sand molds) and R. D. Wood Gate Valves

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Genuine Buffalo Cast Iron
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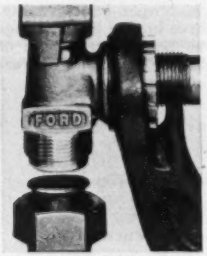
Manhole Frames and Covers

CULPEPER, VIRGINIA

# can YOUR water meters be installed with one hand . . . in 9 seconds?

**NOW . . . *low-cost Ford yokes make possible new standards of speed and simplicity in meter setting or removal***

The Ford yoke shown above can make water meter installation a lightning-quick operation for your maintenance crews . . . cut meter installation time and cost.




Improved Valve, which can be provided as part of Yoke, does away with loose connecting ring, includes standard copper tube nut. Result is easy-to-make, leak-proof joint.

Here's how: With the Ford yoke holding inlet and outlet piping in fixed position (see photo), the meter is 1) simply set in place on the yoke, and 2) made water-tight by a manual expansion connection. The complete job takes only 9 seconds! Yet, speed isn't the only advantage of a Ford yoke. Equally important: Subsequent meter changes need never disturb service line spacing or alignment, eliminating a frequent source of trouble and leaks.

Millions of Ford yokes are in service all over the nation and Latin America . . . proving every day that there is almost no installation that can't be made better with a Ford yoke. Find out now how much maintenance time and money these low-cost units can save you.

***For more information and Sample, write***

**FOR BETTER WATER SERVICES**

**FORD**

**THE FORD METER BOX COMPANY, INC. Wabash, Indiana**

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*. . . longer tool life*
*. . . perfect connections*

**Rigidity on the main . . .**

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**Rigidity in the boring bar . . .**

Three widely spaced boring bar bearings, two in the feed sleeve and one at extreme bottom of boring bar, assure perfect boring bar alignment. Molded nylon lower bearing supports drill when it first contacts the main. Pipe curvature cannot deflect drill—tools give longer effective life. These three boring bar bearings guarantee perfect centering of tool and stop, assuring a pressure-tight connection.

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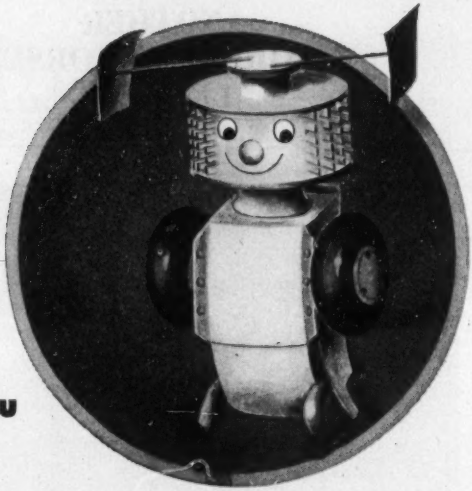
**B-100 Machine**

*These are only a few of the many advanced features of the new Mueller B-100 Drilling, Tapping and Inserting Machine. They are typical, however, of the attention to detail in research, design and engineering that become a part of every Mueller product used by the water industry.*

**MUELLER CO.** — **DECATUR, ILL.**

Factories at: Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario.



have you met

# Dr. Centriline . . .

If not, you should! He can do things for you . . . like making your job easier and saving you money. He's a versatile and somewhat ingenious many-armed creature who specializes in cement-mortar lining the inside of pipes. And he's done this to over 4 million feet of pipe, too—eliminating corrosion and tuberculation . . . increasing flow capacity . . . reducing leakage . . . slashing pumping costs . . . and adding years and years of pipe life. If you'd like to learn more about Dr. Centriline and how he can work for you, just write or call for one of our descriptive brochures.

## CENTRILINE CORPORATION

*A subsidiary of the Raymond Concrete Pile Company*

140 CEDAR STREET
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Branch Offices in Principal Cities of the United States, Canada and Latin America

• CEMENT-MORTAR LINING OF PIPES IN PLACE •

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Illustrating 2 Fairbanks-Morse motor-driven, 4 MGD Fairbanks-Morse centrifugal Figure 5814 Pumps, and 1 - 6 MGD Fairbanks-Morse 300 HP diesel-driven Fairbanks-Morse Figure 5814 Pump.

Designed and engineered by Fay, Spofford & Thorndike, Inc., Consulting Engineers.

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**178 Atlantic Avenue** **Boston 10, Massachusetts**

**Telephone: LAfayette 3-3600**

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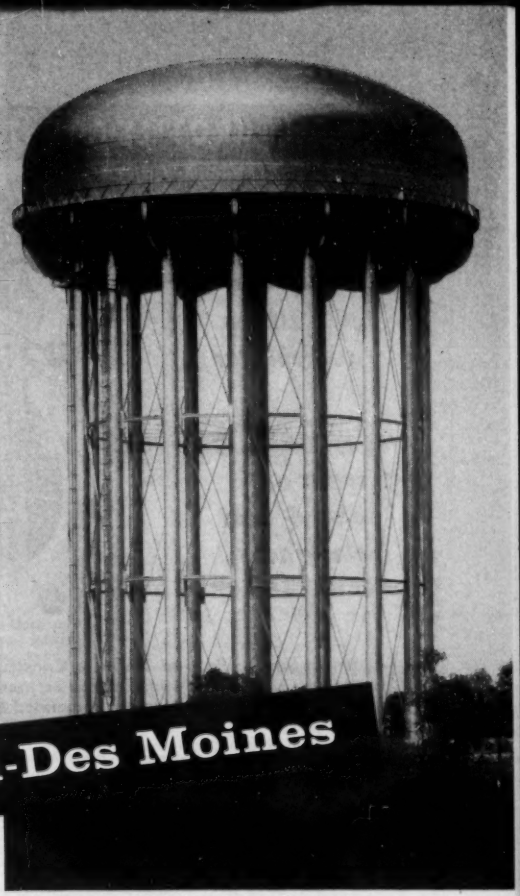
ELEVATED STEEL TANKS

*When your elevated water storage needs are*

# *large in scale*

*depend upon the unequalled experience of*

# Pittsburgh-Des Moines



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● Engineering of highest excellence, precision fabrication and sure craftsmanship in erection have distinguished Elevated Steel Tanks by Pittsburgh-Des Moines since 1897. Write for prompt quotations.

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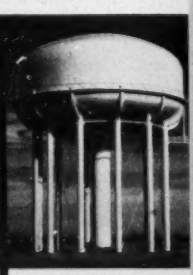
BALTIMORE (26).....Curtis Bay Station

Sioux City, Ia.
2,000,000 Gallons

Fort Wayne, Ind.
1,000,000 Gallons

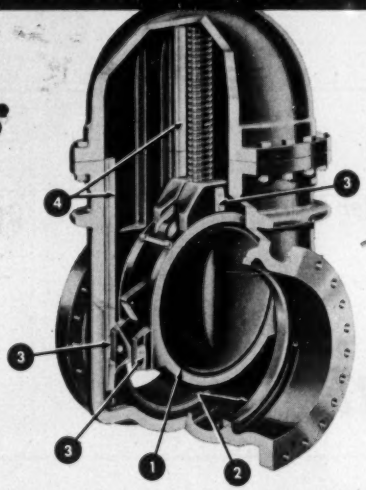


Pueblo, Colo.
1,500,000 Gallons

# SMITH THROTTLE CONSTRUCTION VALVES

## ELIMINATES
*disc tilting and chatter*

## REDUCES
*wear of disc & seat ring faces*




Smith Square Bottom Throttle Construction Valves have all of the time-proven design and construction refinements of standard Smith Gate and Tapping Valves and are recommended for severe service applications such as throttling in a partly open position, daily or frequent operation against high unbalanced pressure, high velocity or installation in a flat position in vertical piping.

The design features consisting of disc shoes and body tracks mechanically lift and hold the disc ring face (1) out of contact with the seat ring face (2) at all points of disc travel with the exception of the fully closed position.

Throttle construction valve discs are provided with three non-ferrous metal shoes (3), precision-machined and jig located. Valve bodies are provided with three non-ferrous metal machined tracks (4). The three disc shoes register with the three body tracks and each shoe is in contact with a track while the valve is unseated and in any partially open position. The bottom section of each track is bevelled to insure that the shoes will not bear on the tracks when the valve is fully closed.

This construction prevents damage to and uneven disc and seat face wear and assures long service life under severe operating conditions.

Single throttle construction is used when the flow is not subject to reversal. Double throttle construction when the flow is subject to reversal.

58

FIRE HYDRANTS · VALVES · SINCE 1896

**THE A.P. SMITH MFG. CO.**

EAST ORANGE, NEW JERSEY

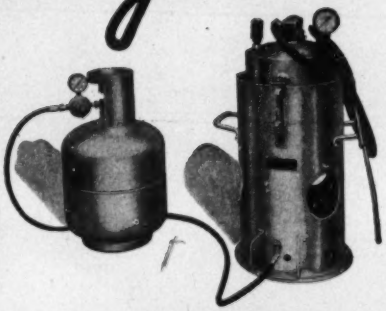

Vol.
19

NOW, YOU CAN

# forget frozen hydrants

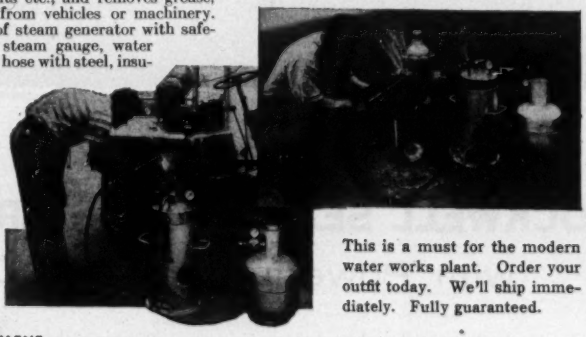
use an

## L-P GAS BURNER STEAM THAWER



**THIS IS THE FASTEST MOST SUCCESSFUL THAWING DEVICE KNOWN IN THE WATER FIELD . . .**

Here is the most practical, most effective, thawing device ever offered the water field. Thaws water pipes, valves, hydrants etc., and removes grease, frozen mud or dirt from vehicles or machinery. Three gallon rustproof steam generator with safety valve, 30 pound steam gauge, water gauge, 6 feet of steam hose with steel, insulated nozzle that can get into tight spots. Can be refilled without shutting off burner. Weight 95 lbs.—20 lb. propane gas cylinder comes with burner—extra cylinders always available.



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This is a must for the modern water works plant. Order your outfit today. We'll ship immediately. Fully guaranteed.

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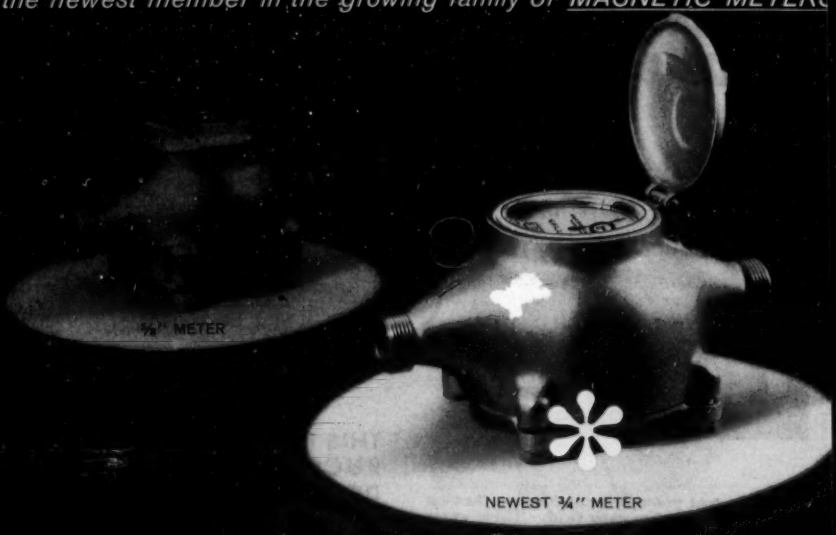
# Announcing...

*the newest member in the growing family of MAGNETIC METERS*




## *NOW A FULL ¾" SIZE

## ROCKWELL SEALED REGISTER METER

### with Powerful Magnetic Drive

Why has Rockwell invested a substantial sum in the development of another, bigger size magnetic meter? Because you asked for it! Based on your tremendous acceptance of our magnetic meter principle, there is now available to you a full ¾" size Rockwell Sealed Register meter to handle larger services. And more and bigger sizes are to come.

With it you can meter ¾" services with the same exclusive advantages proved the country over by thousands of ⅝" Sealed Register meter installations. These include a powerful magnetic drive which (1) eliminates the need for a stuffing box, (2) permits the use of a hermetically sealed, fog-free register and (3) provides an economical, easy to repair construction in which only two parts operate in water.

For full facts on this newest magnetic meter, write Rockwell Manufacturing Company, Pittsburgh 8, Pa.

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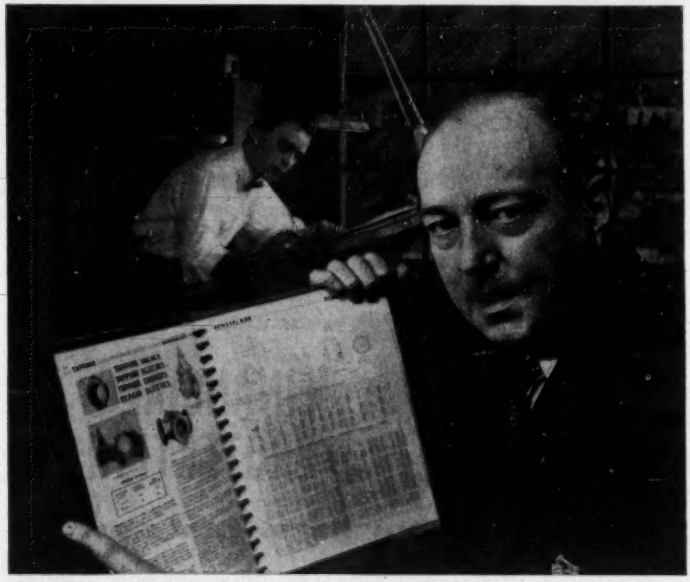
another fine product by
ROCKWELL



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# "L&R gate valves pass our 3-point test!"

Many engineers and waterworks superintendents ask themselves this question before specifying a particular gate valve:

"Does it operate easily, efficiently and dependably?"

Ludlow gate valves and Rensselaer gate valves meet all three of these basic requirements. They give you watertight closure through years of dependable, trouble-free performance. Simple in design and easy to operate, they exceed A.W.W.A. specifications.

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**WRITE FOR THE L&R GATE VALVE CATALOG, showing the most complete selection of outstanding design features available today. There are sizes from 2" to 72", plus custom designing for special applications.**

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VALVES AND HYDRANTS

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## for your most vital service

Water . . . your community's most important single service . . . must be protected by sound financing. The only *sure* protection is the sustained accuracy of your water meters.

If a meter becomes inaccurate, it starts to give away revenue. In home after home, leaks and carelessness go scot-free. The warning voice of the meter is gradually stilled, and wanton waste soon uses up your available water supply.

Worse yet, lack of proper income makes it impossible to build new capacity without tremendous losses. Water shortages soon become critical. Your city's development program soon dies . . . of thirst.

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2818

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POSITIVE CONTROL OF MATERIALS IN MOTION B·I·F METERS FEEDERS CONTROLS

***BUILDERS-PROVIDENCE*** instruments for measuring and controlling flow, liquid level, pressure and weight

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- **NO DANGEROUS AND TROUBLESOME SHUT-DOWNS**

*The story of how composite, wire-wound prestressed liquid storage tanks can effect substantial savings for you is worth knowing. For full information, write to* NATGUN.

"Our 1,500,000 gal. standpipe proved to us that NATGUN Prestressed Tanks are truly maintenance-free. Not 1¢ has been spent on this tank since it was built in 1936.

"Accordingly, in taking bids for New Britain's new 4,000,000 gal. reservoir, consideration was given to Prestressed Tanks ONLY.

"Now our two NATGUN Tanks stand side by side — a testimonial to trouble-free service."

**GEORGE WOOD**
*Chief Engineer*
*Board of Water Commissioners*
*New Britain, Conn.*

**PRESTRESSED TANKS COST ONLY ONCE**

**NATGUN CORPORATION**
101 WEST DEDHAM STREET, BOSTON 18, MASS.

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*Durette Photo Company, Inc.*

CLARENCE L. AHLGREN

President of the New England Water Works Association
1958-1959

NEW ENGLAND WATER WORKS ASSOCIATION
ORGANIZED 1882

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# PUBLIC WATER SUPPLIES OF CONNECTICUT DURING THE 1957 DROUGHT

BY FREDERICK O. A. ALMQUIST*

[*Read February 20, 1958.*]

The unexpected happenings that occur in the operation of a public water supply serve to break any possible monotony and keep the water official alert. While writing this article the writer has just finished reading in the local paper that a broken water main, through danger of cave-ins and explosions, was imperiling a part of Jersey City, N. J., causing the closing of schools and industrial plants in a third of the city—about 1.5 mil gal of water were being lost every hour—and, of course, in 13° weather. A much greater emergency occurred during 1957, when the northeastern portion of the United States experienced an extended dry period, which caused much anxiety to many water-works officials and a great deal of loss to water utilities, farmers and others. Connecticut was among the states that was seriously affected.

After ten months of rainfall deficiency in 1957, rains fell in November and December. In January 1958, only two or three months after drought conditions existed, there were some rumors of possible flood damage. Such are the vagaries of a New England climate, and such are the problems that rise to plague a water-works man. But a good water-works man does not forget, or at least his records should not allow him to forget. It's an ill wind that does not blow some one good, and an emergency once over should be of some help in providing experience to eliminate repetition of conditions over which man has some control. The 1957 drought served to provide considerable experience and should result in much future planning.

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## Rainfall in Connecticut During 1957

The year 1957 was not the driest year on record so far as rainfall is concerned. The first ten months, however, almost set a record. The following table shows the rainfall at three locations in the state by months, as compared to the normal rainfall.

| | Hartford† | | New Haven‡ | | Bridgeport* | |
|---|---|---|---|---|---|---|
| | 1957 | Normal | 1957 | Normal | 1957 | Normal |
| January | 1.95 | 3.74 | 2.37 | 3.89 | 2.33 | 3.86 |
| February | 1.46 | 3.13 | 2.45 | 3.41 | 2.27 | 3.61 |
| March | 1.87 | 3.53 | 2.48 | 4.12 | 2.21 | 4.45 |
| April | 4.43 | 3.55 | 4.62 | 3.89 | 4.71 | 3.94 |
| May | 1.91 | 3.77 | 2.75 | 3.87 | 2.85 | 3.90 |
| June | 2.65 | 3.76 | 0.96 | 3.81 | 0.95 | 3.49 |
| July | 4.59 | 3.93 | 1.35 | 3.66 | 3.66 | 4.27 |
| August | 1.20 | 3.67 | 2.95 | 4.11 | 2.65 | 4.57 |
| September | 1.20 | 3.41 | 2.79 | 3.46 | 2.73 | 3.85 |
| October | 3.35 | 2.70 | 5.13 | 3.00 | 4.57 | 3.74 |
| November | 4.49 | 3.85 | 4.49 | 3.94 | 4.44 | 3.92 |
| December | 6.20 | 3.49 | 5.78 | 3.94 | 5.16 | 3.97 |
| Total | 35.30 | 42.53 | 38.12 | 45.10 | 38.53 | 47.57 |

†Records back to 1868.
‡Records back to 1804.
*Bridgeport Hydraulic Co. — average of 4 stations on watersheds, several miles back from Long Island Sound shore line.

Well above normal rainfall during November and December probably kept the total for the year from being a record low. The deficiency from the normal in Hartford for the year was 7.23 in., New Haven 6.98 in., and Bridgeport 9.04 in. The margin of deficiency was much greater for the first ten months. In Hartford the total rainfall for the first ten months of 1957 was 24.61 in., as compared to a normal rainfall of 35.19 in., or a difference of 10.58 in. In New Haven these figures were 27.85 in., as compared with an expected 37.22 in., or a difference of 9.37 in. The figures for Bridgeport are even more striking. The ten-month rainfall was 28.93 in., as compared to a normal of 39.68 in., or a difference of 10.75 in.

## General Effect on Water Supplies

Needless to say, despite all possible precautions and pleas for conservation, many reservoirs became very seriously depleted. As conditions became increasingly serious, consumers were required to conserve water. This took many forms, such as no lawn sprinkling, no car washing, and finally no use at all except for bare necessities. In at least one city fines were levied against persons for violating emergency rules. Some utilities asked that lawn sprinkling and other use of water be done every other day, with even numbered houses on even calendar days and odd-numbered houses on odd calendar days. These requests sometimes were supplemented with requests for use only during certain hours. Attempts were made to conserve on water in industrial plants, and while at first the conservation did not affect production, later it became serious in many plants. Some utilities, as might be expected, who were fortunate to have planned adequately in advance, had sufficient storage or supply and were never forced to call for curtailment of water for any purpose.

*Questionnaire*

The Connecticut State Department of Health is vitally interested in the adequacy as well as the safety of a public water supply. The depletion of a public water supply may result in serious health hazards, directly or indirectly, and a serious depletion may be dangerous from the standpoint of fire prevention and control.

Certain sections of the General Statutes place the authority for the supervision of public water supplies in the Connecticut State Department of Health. When it was evident that conditions were becoming quite serious, a questionnaire was sent out in October to the water-supply officials. A copy of this questionnaire is shown.

Returns were received from 53 supplies and 4 state institutions. This was considered a good return, as there are several small supplies and many with an adequate ground-water source. Of 40 water supplies involving surface-water sources, 10 were reduced to less than 60 days' supply remaining, and 2 well supplies practically failed.

QUESTIONNAIRE

City or Town _____ Name of Supply _____

Average daily consumption at present _____ Note: All data in million gallons (m.g.)

| Name of Reservoir | Capacity When Full | Present Amount in Storage | Present Amount Available | Additional Amount by Pumping |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Estimated Days' Storage Available _____ Estimated Days' Storage with Emergency Pumping from Storage _____

Steps Being Taken _____

Possible Emergency Sources _____

Steps Taken to Reduce Consumption _____

Notes _____

Date _____ DATA BY _____

## Experiences of Several Utilities

A review of experiences by several utilities, pointing out their difficulties and remedies, is made with the thought that others may encounter similar conditions and thereby profit from them.

One of the first utilities to feel the shortage of water was the city of New Britain. This was undoubtedly because the consumption, much of it industrial, had increased faster than steps taken to prolong the adequacy. Even during the fall of 1956 the city was forced to pump from an emergency brook supply. This was temporarily discontinued during the winter of 1956-1957 and the spring of 1957. The city soon went back to the emergency brook supply and before the end of 1957 was drawing water from 6 emergency supplies. The water-department engineers were aware of a possible shortage, but the city over a period of years had not acted. Emergency supplies used included brooks, ponds, wells and connections with two neighboring public water supplies.

A textile plant in the village of Occum in the town of Norwich operates a small supply, obtained from a 500-ft drilled well, and also owns a small, previously abandoned surface reservoir. The well supply was apparently reduced in yield, and the reservoir supply was used to absolute depletion. A tank truck was pressed into use, carrying water to the consumers for toilet flushing and bathing. Unfortunately, neither the local director of health nor the state department of health was informed, and when the investigation was made, it was revealed that the tank truck was filled with contaminated river water. Had either agency been called immediately, at least the water in the tank truck could have been disinfected. In looking around for an emergency source, a farm reservoir, constructed only the year before with U. S. Dept. of Agriculture aid, under the bureau of conservation was found about one-half mile away. The reservoir held probably 3 mil gal; the water appeared clear, and there was a good yield. A sample of water was collected for analysis, and fortunately a microscopical analysis was made. The water contained a fairly heavy algal growth of the taste- and odor-producing type and required copper-sulphate treatment. Through the use of some

aluminum irrigation pipe with some fire hose and an emergency pump, the local reservoir received enough water from the farm reservoir to carry over the emergency.

In the village of Bethel, the water is obtained from reservoirs, furnishing a high- and low-service system, supplemented by water from a gravel-packed well. The well has been a needed addition to the supply. While drawing at a normal rate from the well, a satisfactory water was obtained. However, when the rate was increased, the hardness increased from about 100 ppm to 400 ppm, causing complaint, and a reduction in the pumping rate had to be made. Another well has been constructed.

The city of Bristol ran into some difficulty in spite of the construction of a second gravel-packed well, yielding in excess of 1,400 gpm. Chlorinated reservoir water was pumped into the clear well of the filtration plant to relieve the load on the plant. In addition, a collecting basin was excavated on the brook below the plant, and this water was pumped back into the reservoir after chlorination. The basin picked up water from a small watershed, the overflow from the wash-water lagoon below the filtration plant, and possibly some seepage through the dike from the reservoir.

A small reservoir, furnishing water to three small villages in the town of Killingly by the Powdrell and Alexander Memorial Water Association, became entirely depleted because of lack of run-off. Fortunately a factory in the lower village had a drilled well of good capacity with water of good quality. There already existed a connection for mutual aid, the two supplies being separated by two gate valves with an open drip valve between. It was a simple matter to change the valves and supply the villages from the factory well.

The source of water supply for the Cromwell Fire District is a series of driven and gravel-packed wells. When the yield seemed to diminish, the casing was pulled and the well made deeper with an apparent increase in the yield. Such a procedure, however, is not always recommended for increasing the yield.

The Crystal Water Co. of Danielson felt the need of additional water. The company already had one gravel-packed well to augment the surface-water source. An eight-inch test well was

driven, preparatory to the construction of another gravel-packed well. The yield was good, and a pump was placed on the test well for a quick supply. With the emergency over, the gravel-packed well will be finished.

The Farmington Water Co. has a surface water which is filtered through slow sand filters and chlorinated. Fortunately a connection had been made some time ago to a transmission main from the Nepaug Reservoir of the Metropolitan District of Hartford County. When the local reservoir became low, a switch was made to the emergency connection.

Part of the water supply of the Connecticut Water Co., Guilford Division, is obtained from wells, and part from a reservoir system. When dry weather persisted and it was necessary to maintain a high rate of pumpage from one gravel-packed well, it was decided to recharge the ground water by raising a dam and thus the ground-water level. This brought the outside surface water close to the well. It also flooded over new vegetation, which caused a pick-up of organic matter in the ground water and resulted in a disagreeable and unbearable chlorophenol-type taste in the delivered water. The rate of chlorine dosage was lowered to an absolute minimum with daily bacterial analysis of the water during the emergency.

This same water company was troubled considerably with near-depletion of reservoir water in the Naugatuck Division. Only 30 days' storage remained at one time. Factories were asked to curtail water consumption to a point where production was lessened. This company lost many thousands of dollars in revenue. Future plans call for the raising of one dam and diverting water from an adjacent watershed. This will take some time. In the meantime, an emergency pumping station was set up on a brook. Even so, considerable delay was experienced until objectionable watershed conditions on the brook could be corrected.

To add still more worries to the officials of the Connecticut Water Co., the reservoir supply of the Stafford Division became exceedingly low. Three wells on the watershed were pressed into use. Normally only one is used because of a high iron content in the ground water. The company had previously installed super-

chlorination equipment with sedimentation, and this, with some dilution from the surface water, resulted in a usable water. Three pond supplies were also surveyed, one being located on the watershed. This latter pond, though not large, would have provided some additional water very easily and simply.

The Jewett City Water Co., served by a reservoir and gravel-packed well, found itself in difficulty. Time was consumed in surveying another watershed which was finally not needed. One of the leading factories helped by reducing the consumption from the public water supply appreciably, when it drew water for process work from an adjacent pond.

The Manchester Water Department had anticipated a possible water shortage, when a year or two previously it purchased a large factory pond-water supply, equipped with chlorination and a rapid-sand filtration plant, already connected and ready to operate. The water department has also completed several wells to augment its surface supply.

The city of Meriden sought and obtained the use of a fairly large factory water supply of good quality. The water was already being chlorinated and was ready for use. Another abandoned factory pond with a 20-inch transmission line already in the ground was surveyed for possible use. The necessary piping connections were made ready for installation, if necessary.

A series of wells formerly abandoned by the Lakeville Water Co. were again used during the emergency. They were formerly abandoned in favor of some new ones with a less degree of hardness.

Several water utilities in Connecticut have constructed wells on or above watersheds with discharge to storage reservoirs or drainage areas of storage reservoirs. The Bridgeport Hydraulic Co. has five gravel-packed wells, estimated to yield 12 mgd, which are pumped onto one of its watersheds. Others in the same area are in the process of construction. The Mystic Valley Water Co. completed one during the year just above its storage reservoir. If there are no well locations near the distribution system, there may be some near the collecting system.

Water for the New Milford Water Co. is obtained from a series of reservoirs. A pipeline conveys water from the reservoir

farthest away. The hydraulics of the line are such that advantage cannot be taken of as great a flow as is available and desirable. A pump can be used frequently to improve the flow. Booster pumps can also be placed on transmission lines to distribution systems, to maintain pressures when the consumption is heavy during dry-weather periods.

Sometimes water can be found relatively near distribution systems, but the pipeline hydraulics are poor. The town of Southington was limited in the water that could be obtained from a second gravel-packed well, until a larger pipeline could be installed.

A reservoir and gravel-packed well furnish water to the system of the Thomaston Water Co. The reservoir water is filtered through a rapid-sand-type filter and chlorinated. Setting the pump a little deeper in the well appeared to provide a little more water. However, the improvement was not enough, and the reservoir elevation was dangerously lowered. The filtration plant had to be bypassed with chlorination, and finally an emergency connection was made to a transmission main of the city of Waterbury. Difficulty arose when the connection was made to the Waterbury line. It was almost impossible to find a valve in the Thomaston system that would close the water flow, so that work could be done on the piping.

Two reservoirs, one above the other, furnish water to the system of the Unionville Water Co. in the town of Farmington. They became alarmingly low and an existing connection to the Nepaug Reservoir supply of the Metropolitan District of Hartford County was turned on. When the local reservoirs were again full, they were placed back in use. Complaints poured in, and a microscopical analysis showed the presence of algae. After an investigation, it was recommended that copper sulphate be added to the reservoirs. The complaints stopped for about a week, then came in again. Further investigation showed that the lower reservoir was treated with copper sulphate, but the upper one, being a little larger and more difficult to treat, was not. After both reservoirs were treated, no further complaints were received. While it did not occur during the 1957 drought, one reservoir at the time of the previous dry period was drawn down below

the intake level. A raft was constructed and water pumped into the intake line from a pump on the raft.

A small water company, known as the Westover Water Co., in the town of Middlebury obtains its supply from a series of wells, a spring and an infiltration gallery. In spite of the construction of a gravel-packed well during the previous year, the total yield did not meet the demands of the system. Water was pumped from a nearby lake into one of the wells, from which it was repumped, after chlorination, into the distribution system.

The Woodbury Water Co. reservoir became quite low during the dry period. Because the hydraulics of the piping system were poor, a recently constructed standpipe would not fill. To obtain more water and to aid the pressure conditions, a well was constructed at the farther end of the system from the reservoir. The well was used successfully during the dry period.

The Connecticut State Hospital at Middletown for several years has been consuming more water from its collecting system than the system is estimated to yield in an extended dry period. Several improvements were made in piping and pumping to take the fullest advantage of the existing supply. Since the danger was realized, another reservoir was constructed during the past year which, though not quite ready for the 1957 dry period, will be available for any future dry period.

## Summary of Lessons Learned

The lessons listed below have been taken from experiences gained in the 1957 drought only. There are many more that could be listed. These experiences or lessons are reviewed with the thought that they may be of help to some water-works official who might find himself in a similarly unfortunate system.

### *General*

1. In Connecticut a sanitary-code regulation exists, requiring the local water-utility officials to communicate with the state department of health in any emergency affecting the water supply. With a broad general knowledge, officials of the state department of health can frequently be of considerable assistance. The distribution of an unsafe water by means of a tank truck, as was

done by one of our small factory utilities, could have been averted.

2. An effort should be made by adjacent utilities to be of mutual aid to each other. This should be considered before there is an actual emergency, and such things as the following could well be studied:

a. Relative pressures of adjacent piping systems and the amount of water available.
b. Sizes of piping at point where an interconnection might be made.
c. In cases where pumping may be necessary, the locations and arrangements necessary for an emergency pumping station.

3. The hydraulics of the distribution system should be studied, and a thorough knowledge of weaknesses should be acquired.

4. Similarly, the hydraulics of the collecting system should be known. Existing transmission lines or diverting lines or tunnels may not offer best efficiency and also may be losing capacity faster than anticipated.

5. Possible emergency equipment should be checked constantly, such as:

a. Amount and type of piping on hand.
b. Pumps available, electric- or gas-driven, and arrangements necessary for their use. This would include possible power lines.
c. Disinfection equipment.
d. Emergency housing that may be necessary for pumping equipment, disinfection equipment, etc.

6. Valves should be checked in the distribution system as to their condition. It may be necessary to close one or more to make emergency connections.

7. If certain lines have not been in use either before or after the emergency and have been standing full of water, they should be flushed thoroughly before being placed in use. Water may deteriorate on standing to a point where it may have objectionable characteristics.

*Surface Waters*

1. When surface waters are involved, studies should be

made of any possibilities of emergency supplies. These should include:

a. Amount of water available with assurance that it will be available when required.
b. Condition of watershed should be known — sufficient time should be allowed to make any necessary corrections of undesirable or potentially dangerous sources of contamination.
c. Ice ponds or former ice ponds are usually good sources of emergency supply, because previous watershed inspections have undoubtedly been made.
d. Factory ponds can frequently be used in an emergency. Knowledge should be obtained as to the amount available and previous commitments.
e. Frequently lost water from seepage through dams can be impounded below a reservoir and pumped back to the reservoir. Wash-water below a filtration plant can sometimes be salvaged in this way.

2. Any surface water should be examined as to physical, chemical and bacterial quality before being placed in use. The examination should include a microscopical analysis for objectionable algal growths. This should also be done if a depleted reservoir has filled and it is desired to place it back in use.

3. Should it be necessary to add copper sulphate to a reservoir, investigation should be made of any reservoirs upstream which might possibly seed a lower reservoir.

4. If the prolonging of the adequacy of a surface supply is needed and a new reservoir is indicated, an early start should be made. After a study has shown a possible site, it should be obtained immediately and the necessary work started, since there is usually quite a long period of time from the early stages to the completion of such a project.

*Well Supplies*

1. Normally yield tests are of too short a duration of time. Eight hours is too short a period, and 24 hours should be considered as a minimum length with observations of draw-down and recovery. A week's test or even two weeks of continuous pumping with the proper measurements and records should be considered. One gravel-packed well, 300 to 400 ft from a brackish stream, assumed some of the characteristics of the stream, and rate of pumpage had to be reduced. Another gravel-packed well

increased from approximately 100 ppm to 400 ppm in hardness when heavily pumped. A good yield test will provide the recommended maximum rate of pumping. The water during a yield test of several days or more should be examined near the beginning of the test and also at the end.

2. Occasionally adding depth to a well may provide some additional yield, but dependence cannot be placed on it. Frequently some additional water can be obtained by setting the pump a little lower in a well, to obtain a greater draw-down.

3. Recharging of ground water so as to keep the ground-water level up, by pooling water on the surface in the vicinity of a well or wells, has been found helpful in a great many instances in improving the yield. Care should be exercised that the recharging water contains no objectionable elements or that it does not come too close to the well. Under no condition will the Connecticut State Department of Health approve a well supply where surface water can come within a 50-foot horizontal distance from the well.

4. There is a strong trend for public water utilities to supplement their existing supplies through the use of wells. This is because of the high cost of reservoirs, the rapidity of development of wells if successful, and likelihood of good-quality water without extensive treatment. These wells must be located where ground water is available. This location is not always at the most convenient point for the utility. Normally it is most desirable to locate a well near a pipeline in the distribution system, on the opposite side from the reservoir. However, in many cases wells can be found on watersheds or close to watersheds above reservoirs. These have worked out very nicely in many cases in Connecticut. Iron and hardness should be watched in connection with well-water quality.

5. Many factories have provided themselves with wells. These wells are frequently potable and may be available to public water supplies in emergencies.

## Conclusions

1. A drought or any other emergency that causes a reservoir to become depleted is very likely to result in many objectionable

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5. Many factories have provided themselves with wells. These wells are frequently potable and may be available to public water supplies in emergencies.

## Conclusions

1. A drought or any other emergency that causes a reservoir to become depleted is very likely to result in many objectionable

and some serious conditions. The water in a low reservoir without circulation is inferior in quality to that in a full reservoir. The low water also may result in poor fire protection with lessened pressure.

2. A vicious cycle begins when there is a shortage of water. Requested curtailment in general use of water causes loss of revenue to the utility, and loss of revenue makes improvement in adequacy of supply more difficult. In the meantime, curtailment in use of water in industry causes curtailment of work, loss of wages, and difficulty in payment of taxes and bills in general. One moderately large utility reported that its loss in revenue during the 1957 drought was in the vicinity of $45,000, and the cost of obtaining and operating emergency sources was in the vicinity of $105,000.

3. A drought emergency should point out weaknesses in systems which should serve at least two purposes: (1) to stir the management into action and (2) to inform the consumers of public water-supply conditions in their area.

4. Improvements or additions to public water supplies are sometimes complicated and need considerable study and planning. Water utilities will frequently need to call in consulting engineers for these problems, as it is important that the best solution possible be made toward maintaining this most important commodity we are privileged to use and enjoy.

5. As a result of an emergency, such as from an extended dry period, water-utility managements should keep pressing their boards of water commissioners or directors for action. A long period of time often elapses between the planning stage and the final execution of a project, and no time should be lost in starting, after a necessity has been demonstrated. The public, chambers of commerce, manufacturing associations and other organizations should support improvements, whenever necessary.

# THE EXPERIENCES OF NEW BRITAIN WITH THE 1957 DROUGHT

BY GEORGE W. WOOD*

[*Read February 20, 1958.*]

In 1957 we had a very serious drought. This is not news to many of you, for you had your problems too during this period. If the various methods used to solve this problem, however, were known to all of us, it might be helpful in the future.

The city of New Britain, Conn., certainly had a problem during this drought period but managed to come through, and at no time did anyone have to go without water for all regular uses, nor did any manufacturer have to curtail his operations for lack of water.

Before telling you of our experiences during this past summer let me give you a little background history.

The first water was brought to the city from Shuttle Meadow Reservoir in October, 1857. The second addition to the supply was the Wolcott Reservoir, constructed in 1898. The third and last surface-supply addition was the Whigville Reservoir, constructed in 1908 (see Figure 1).

The next addition to the supply was the construction of a well supply at White Bridge in Forestville in 1922, improved in 1945 and now capable of supplying about 3 mgd. The third and last addition was the construction of the Patton Brook well in Southington in 1950, capable of producing 1 mgd.

The three reservoirs provide a total storage capacity of 1,530 mil gal, inadequate for a population of 90,000 people. The safe yield of the system at the present time is between 9 and 9.5 mgd, approximately 50% being used by industry.

Table 1 gives the average daily consumption and the monthly rainfall for the past three years.

This table shows clearly that throughout 1955 and 1956 the average daily consumption was greater than our safe yield.

*Engineer, Board of Water Commissioners, New Britain, Conn.

TABLE 1

| Month | 1955 Ave. daily consumption (mgd) | 1955 Precipitation in inches | 1956 Ave. daily consumption (mgd) | 1956 Precipitation in inches | 1957 Ave. daily consumption (mgd) | 1957 Precipitation in inches |
|---|---|---|---|---|---|---|
| Jan. | 9.632 | 0.58 | 10.135 | 3.19 | 8.983 | 2.34 |
| Feb. | 10.293 | 3.67 | 10.531 | 4.27 | 8.579 | 1.97 |
| Mar. | 10.677 | 5.75 | 10.139 | 5.99 | 8.781 | 2.25 |
| Apr. | 9.530 | 4.27 | 10.427 | 3.72 | 9.610 | 5.11 |
| May | 10.600 | 1.49 | 10.571 | 2.38 | 10.495 | 2.11 |
| June | 12.180 | 2.02 | 11.894 | 4.15 | 11.531 | 2.60 |
| July | 12.160 | 1.58 | 9.933 | 4.75 | 8.900 | 1.92 |
| Aug. | 12.660 | 18.08 | 11.985 | 1.61 | 7.965 | 3.49 |
| Sept. | 11.227 | 5.02 | 10.473 | 3.92 | 7.664 | 2.00 |
| Oct. | 10.794 | 14.46 | 10.755 | 1.69 | 7.576 | 2.82 |
| Nov. | 10.540 | 6.58 | 9.966 | 5.12 | 7.563 | 4.25 |
| Dec. | 10.319 | 1.00 | 8.162 | 5.35 | 8.127 | 7.33 |
| | | 64.50 | | 46.14 | | 38.19 |

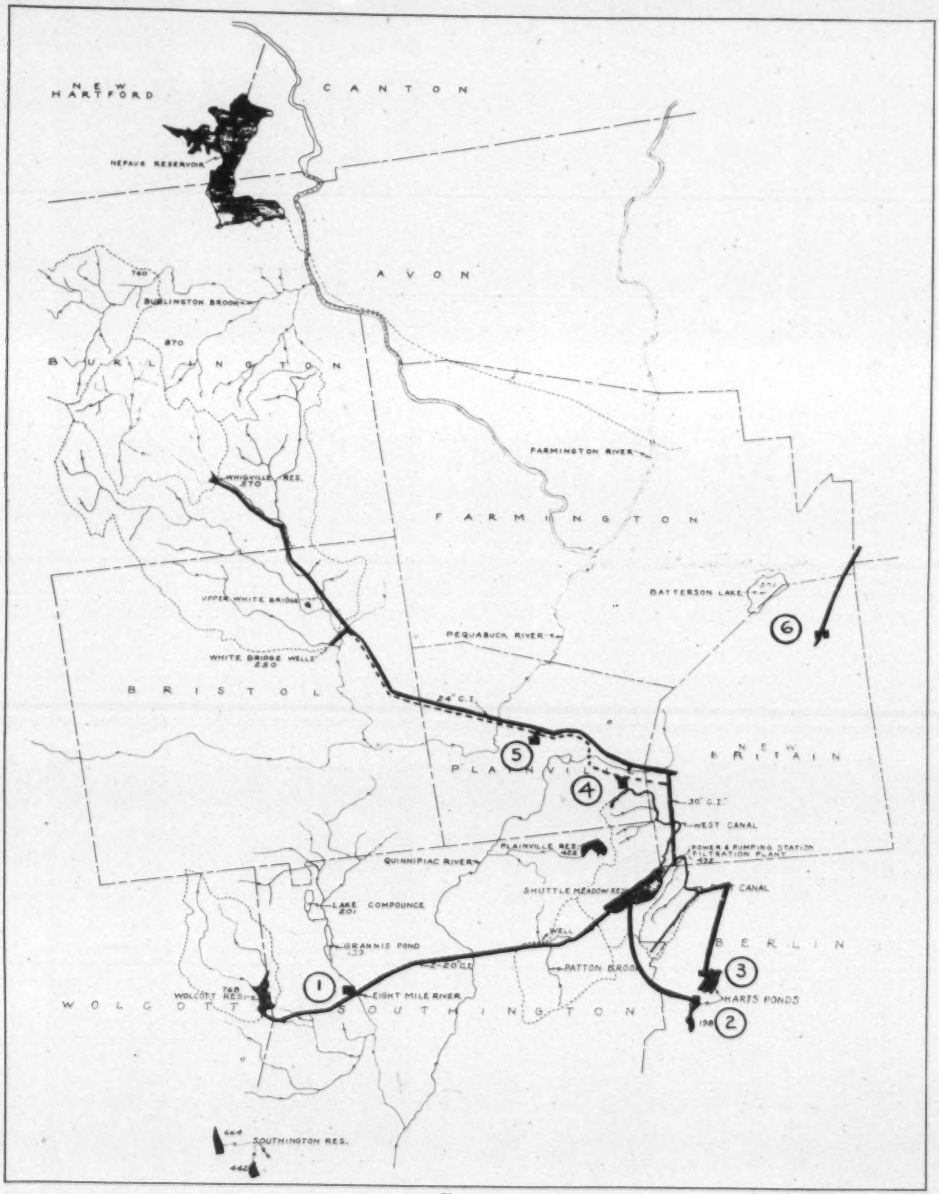
NEW HARTFORD
CANTON
NEPAUG RESERVOIR
AVON
BURLINGTON BROOK
BURLINGTON
WHIGVILLE RES.
270
FARMINGTON RIVER
FARMINGTON
BATTERSON LAKE
UPPER WHITE BRIDGE
PEQUABUCK RIVER
WHITE BRIDGE WELLS
220
BRISTOL
24" C.I.
NEW BRITAIN
PLAINVILLE
30" C.I.
WEST CANAL
PLAINVILLE RES.
POWER & PUMPING STATION (FILTRATION PLANT)
QUINNIPIAC RIVER
SHUTTLE MEADOW RES.
CANAL
LAKE COMPOUNCE
201
GRANNIS POND
WELL
BERLIN
20" C.I.
PATTON BROOK
HARTS PONDS
WOLCOTT RES.
EIGHT MILE RIVER
WOLCOTT
SOUTHINGTON
SOUTHINGTON RES.
664
442
1
2
3
4
5
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FIG. 1.

In 1955, if we had not had those disastrous floods of August and October, we should have had a water shortage.

Even with consumption greater than safe yield and precipitation less than normal we were able to maintain 100% storage until the middle of June, 1956. Then our storage started to drop until the low point was reached on Dec. 8. The total storage at this time was 579 mg, or 38%.

Table 2 shows the total water in storage on the first of each month in million gallons and percentage of total storage.

TABLE 2

| | 1956 | | 1957 | | 1958 | |
|---|---|---|---|---|---|---|
| | Storage in mg | % of total | Storage in mg | % of total | Storage in mg | % of total |
| Jan. | 1,404 | 92.12 | 800 | 52.48 | 954 | 62.54 |
| Feb. | 1,382 | 90.68 | 861 | 56.51 | 1,308 | 85.77 |
| Mar. | 1,505 | 98.70 | 899 | 58.99 | | |
| Apr. | 1,546 | 100.00 | 955 | 62.63 | | |
| May | 1,570 | 100.00 | 1,212 | 79.50 | | |
| June | 1,459 | 95.69 | 1,087 | 71.30 | | |
| July | 1,339 | 87.80 | 897 | 58.86 | | |
| Aug. | 1,237 | 81.13 | 735 | 48.20 | | |
| Sept. | 1,002 | 65.74 | 608 | 39.80 | | |
| Oct. | 850 | 55.77 | 508 | 33.30 | | |
| Nov. | 671 | 43.99 | 463 | 30.39 | | |
| Dec. | 596 | 39.06 | 551 | 36.15 | | |

In November, 1956, an appeal was made to the public to conserve water. The city endeavored to obtain assistance from the Corps of Engineers in Springfield and Boston and from the Civil Defense authorities in Connecticut, but in each case the answer was the same: "Did not have any authority to render aid in such a case."

The pipeline between Wolcott Reservoir and Shuttle Meadow Reservoir crosses the Eight Mile River in Southington. This river is not large but looked like a good possibility for an emergency connection. But the city did not have the right to use the property or the water. Contacts were made with the property owner, the Southington Water Co., and the Selectmen of the town of Southington.

When permission was granted to use this source, a 1,000-gpm pump, coupled to an industrial gas engine, was purchased and installed. The point of pick-up was 21,300 ft from Shuttle Meadow Reservoir and at such an elevation that it was necessary to pump against approximately a head of 250 ft. This unit was operated intermittently until April, 1957.

It became evident in May that, unless we had a wet summer, we were going to be in trouble. Watering of lawns and gardens was put on a restricted basis. As the summer progressed and conditions continued to get worse, more restrictions were placed upon the use of water and more emergency supplies were put into operation.

In July the following notice was inserted in the local newspaper:

"Lack of rainfall and the large use of water has brought about a critical shortage of the amount of water available. In order to conserve the present supply the following restrictions are put into effect at 12:01 A.M. Wednesday, July 24, 1957.

"1. No outside use of water for any purpose whatsoever, including hoses, sprinklers, lawn, garden, car washing, wading and swimming pools.

"2. No Business or residential use of City water for air conditioning systems or units not equipped with water recovery units as defined by ordinance, Chapter XVIII, Section 17.

"3. No residential or commercial car washing.

"Violation of the above is considered a waste of water and subject to a penalty for each offense, a fine of not less than five nor more than twenty-five dollars.

"All users of New Britain water must comply with the above restrictions.

The ordinance referred to as Chapter XVIII, Section 17, was approved by the city officials on July 19, 1956, and is as follows:

"Chapter XVIII of the Ordinances of the Common Council as amended is hereby further amended by adding thereto the following: Section 17. No owner or occupant of any premises may install and use air conditioning and refrigerating equipment utilizing water from the public supply as a cooling agent unless said owner or occupant uses water conserving equipment.

"Existing installations are required to conform with this regulation before June 1, 1957.

"The Board of Water Commissioners shall be the sole judge of what is non-conserving air conditioning and refrigerating equipment.

"All water consuming units must be registered with the Board of Water Commissioners. Existing units must be registered during March 1957. New units must be registered within 30 days after installation."

Mayor Morelli appointed a committee composed of citizens representing a cross-section of the community. This committee was known as the "Citizens Advisory Committee for Conservation of Water" and performed a very good job of keeping the public conscious of the water shortage and thinking of methods to save water. Newspapers, radio and television stations did an exceptional job of keeping the public informed of what was being done to maintain a supply of water.

Restrictions and publicity were not the only means used to alleviate the situation. Six emergency supplies were put into operation. Obtaining the right to use these various sources and putting them into operation was not easy.

The first emergency supply put into operation was the Eight Mile River. This source was used during the first part of 1956. The industrial pumping unit installed was not intended to be run continuously for many days at a time and therefore gave us a maintenance problem.

Mayor Morelli tried again to get help from various Federal agencies and again was turned down. However, after many persistent and persuasive telephone calls, the Civil Defense Authorities agreed to loan us some equipment. At a location about 25 miles from New Britain the CD maintained a storage warehouse, holding pumping units, pipe, couplings and valves.

With our own equipment we transported a pumping unit with some fittings, couplings and valves to the Eight Mile River location. This unit had a capacity of 1,500 gpm against a 230-foot head. At times when enough water was available both units were operated. There never was a time when at least one unit could not be operated.

In the neighboring town of Berlin there are two ponds known as Hart's Ponds, owned by the Continental Can Co. This firm was contacted, and permission was granted to use these ponds. Two installations were made here. Hart's Pond #1 was about 2½ miles from Shuttle Meadow Reservoir, and there was a difference of elevation to overcome of about 350 ft. Two CD

pumping units, 2½ miles of 8-inch steel pipe, couplings, fittings and valves were transported and installed. One unit was installed at the pond and the second unit about ⅓ of the distance toward Shuttle Meadow.

After a few weeks of operation it was decided to replace the two CD units at two different locations with two electric pumps, connected in series, at the pond. This installation allowed us to obtain twice as much water at half the cost of operating the CD units. Each electric pumping unit has a capacity of 1,000 gpm at a 230-foot head and is coupled to a 100-hp motor.

In order to lay the 2½ miles of 8-inch pipe along the side of the road, it was necessary to obtain permission from the towns of Berlin and Southington. The city of New Britain had to carry additional insurance, in order to protect the Continental Can Co., the town of Berlin and the town of Southington.

Hart's Pond #1 was used by a fishing organization, and the city had to agree to stop pumping in case the pond was lowered to a point where it would become dangerous to fish life. This low point was to be determined by the Connecticut State Fish and Game Association.

With the installation of the electric pumps at Hart's Pond #1 it was decided to install the two CD pumps at Hart's Pond #2. The two pumps were moved, and another 2½ miles of 8-inch pipe were obtained and laid along wood roads and through the woods, discharging into the East Canal.

Many offers of help were received and they all had to be investigated. Most of the offers proved of little help, but one offer of a well was worth using. This well was in a quarry and was reputed to deliver 350 gpm. The only pipeline anywhere near this well, connecting with our system, was a 36-inch transmission line under construction. Fortunately a hydrant was to be installed across the road and about 500 ft away from the well. It was decided to connect to the 36-inch line at this point. In order to allow the contractor to continue work on the 36-inch line, it was necessary to install a 30-inch valve. The 30-inch valves were not due for delivery for several weeks, but with the cooperation of the valve company a valve of the kind called for

was located in New Jersey. This valve was installed and a connection made at the hydrant location.

The well was equipped with a deep-well pump, capable of delivering 350 gpm into an 11,000-gal open tank. The operation of the well pump was controlled by a float valve in the tank. The city purchased a 350-gpm pump with a 35-lb discharge head and connected it to the 11,000-gal tank. A low-water cut-off was installed, to protect the unit. This installation was very successful and really produced 350 gpm day after day for about 60 days.

The fifth emergency connection was the connection to the Plainville Water Co. There was an existing connection between the two systems, but, in order to get the water from their system to ours, it was necessary to make some changes in the piping and to install a 700-gpm pump, discharging against a head of 100 ft, coupled to a 25-hp electric motor. At this installation we were limited to 500,000 gpd, obtaining this quantity between the hours of 8:00 PM and 7:30 AM.

The sixth and last emergency supply was the connection to the Hartford Metropolitan District. This connection required the use of about 2,100 ft of 8-inch steel pipe to tie in the two systems. A 1,000-gpm pump, discharging against a head of 230 ft and coupled to a 75-hp motor, was installed.

These emergency supplies, coupled with a substantial decrease in consumption, enabled us to pull through until December, when abnormal rainfall eased the situation considerably. The precipitation in January continued above normal, and the resulting run-off brought the supply back to the point where restrictions could be lifted and the emergency supplies shut down.

About 530 mil gal of water were delivered by these emergency supplies. In order to get the 530 mil gal, it cost the department an additional $106,000. The decrease in consumption produced a further loss of about $65,000 in income.

The experiences of this past year could be considered a blessing in disguise. The public is now very much aware of the necessity of increasing the supply and has been clamoring for action. A consulting engineering firm has been retained to make a complete study of the needs of the city as regards water, and this firm has promised a complete report for about March 1st. I

certainly hope that action on the report will be taken and additional source of supply will be developed.

I cannot close without expressing thanks to all the individuals and agencies that made their services available to us and cooperated so completely.

# PUMPING PROBLEMS IN WORCESTER, MASSACHUSETTS

BY CHARLES B. HARDY*

[*Read March 20, 1958.*]

The city of Worcester uses about 8½ billion gallons of water each year. The supply consists of ten storage reservoirs, which have a total capacity of 7¾ billion gallons. Nine of these reservoirs, holding 6½ billion gallons, are so situated that the water flows by gravity into the distribution systems. Yet in 1957, more than 70% of all water used was pumped at least once, and some of it as many as three times.

Normally the percentage pumped would be much lower. It was only 33% in 1956 and 30% in 1955. For the past ten years, it has averaged 40%.

Worcester has many hills, and it varies in elevation above sea level from a low of 359 at Lake Quinsigamond to a high of 1,056 in West Tatnuck. Moreover, the hills are not concentrated in any one section of the city, but are spread around from boundary to boundary. In general, the highest hills are in the northwest section. This great variation in elevation has led to the development of three separate water-distribution systems, known as the Low, High, and Super High.

## The High Service System

The High System is supplied from a distributing reservoir known as Lynde Brook, situated in the Cherry Valley section of Leicester (see Figures 1 and 2). The flow from a series of four Kettle Brook Reservoirs, located in the next valley to the west, is also diverted into this reservoir. Even though all five of these nearly always fill each spring, the amount of water available has not been sufficient for the demands on this system for many years. The safe yield of this watershed has been estimated at 3.5 mgd, while the present demand on the system is 13 mgd.

*Superintendent, Bureau of Water, Worcester, Mass.

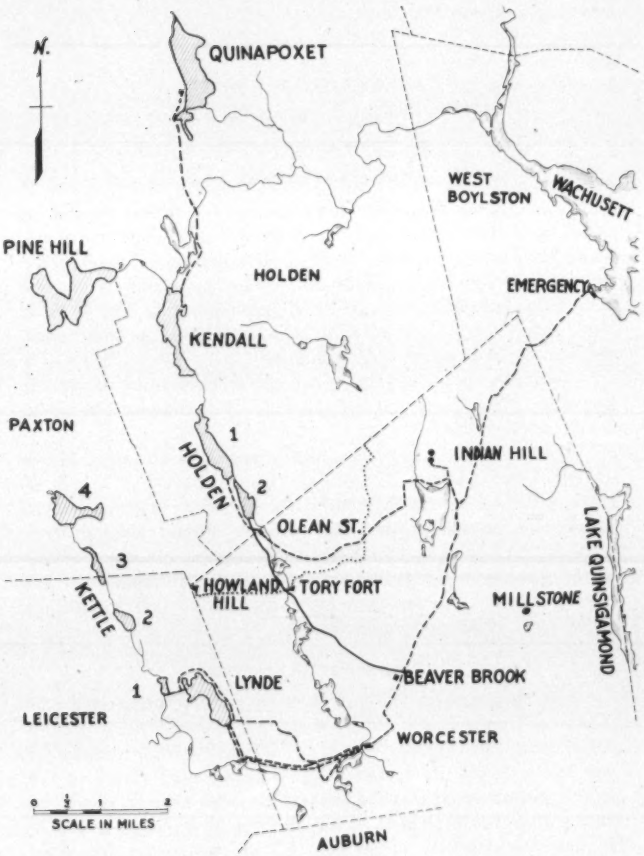


FIG. 1.—SOURCES OF WATER SUPPLY, WORCESTER, MASS.

# WATER SUPPLY WORCESTER, MASS.

# FLOW CHART AND RELATIVE ELEVATIONS

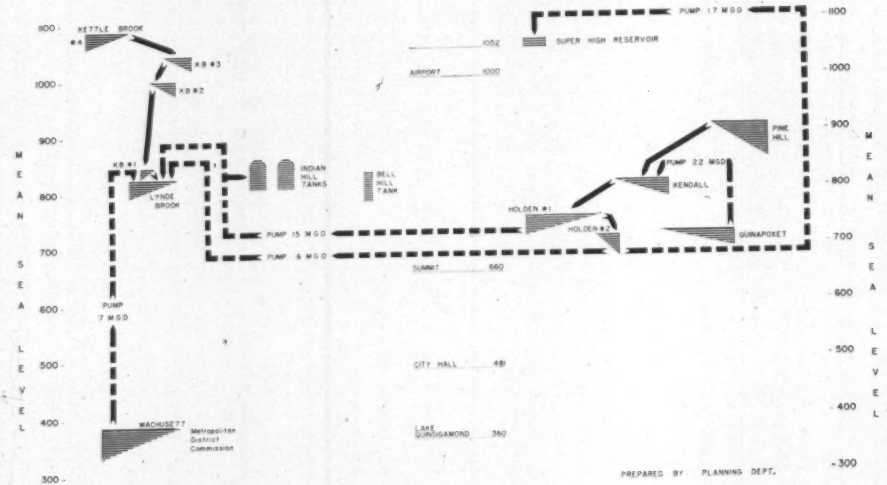


FIG. 2.

## The Low System

The distribution reservoir for the Low System is located on Tatnuck Brook just north of the Worcester-Holden Line, and is known as Holden Reservoir #2. Above this, and supplying it, are Holden Reservoir #1, which was the first one constructed on this system, Kendall Reservoir, and Pine Hill Reservoir. The two Holdens and a part of Kendall are on the Blackstone River watershed. The larger part of Kendall, including the dam and spillway, and Pine Hill are on the Nashua River watershed. The water from Pine Hill is normally discharged through a brook and canal into Kendall Reservoir. However, it can be wasted directly into Asnebumskit Brook, if desired. Kendall Reservoir overflows into Asnebumskit Brook also. These waters flow through Eagle Lake into the Quinapoxet River and on into the Metropolitan Wachusett Reservoir.

Pine Hill is the largest reservoir, with a storage capacity of 2,971 mil gal, but it has a watershed area of only seven square miles. The records show that there have been ten years since 1928 in which this reservoir failed to fill completely. But Kendall and the two Holdens, with a combined watershed area of 7.68 sq mi, have a total capacity of only 1,778 mil gal and often spill to waste.

The safe yield from this system has been estimated at 11 mgd, and the present demand is about 10 mgd.

## Wachusett Pumping Station

Back in 1911, before Pine Hill had been built, and while Kendall was under construction, the city was faced with a serious threat of a water famine early in the summer. Various emergency measures were taken, which carried the city through the fall. A wooden flume carried the water of Asnebumskit Brook across the Kendall Basin. Water from Eagle Lake was pumped into this flume also. But the decision to take water from the Wachusett Reservoir had the more lasting effect.

That the situation was really desperate may be judged from the action taken by the City Council. On August 14th, it authorized the Mayor to secure a competent consulting engineer

"upon terms as may in his judgment be expedient." The Council then ordered that "The Consulting Engineer, under the direction of the Mayor, be and he is hereby authorized, empowered, and requested to lay the necessary pipes and connections, and to erect and equip a pumping plant of suitable capacity, and do all other necessary things, in order to procure for the City of Worcester an emergency water supply from the Metropolitan Water Basin, etc."

The Mayor immediately hired Charles A. Allen, who had agreed to undertake the control of the construction, on the condition that the Council should give him absolute authority. On August 15th he hired Stone & Webster to build the pumping station on a cost-plus basis; ordered three pumps; made an agreement for electric power; ordered the cast-iron pipe and fittings, and sent letters to several contractors, requesting proposals for the laying of the mains.

The station was located in West Boylston on the shore of the reservoir, near the intersection of Temple and Hartwell Streets. A 30-inch cast-iron main was laid along Hartwell St. to Burncoat St., and in Burncoat St. to Mountain St. East, a distance of 11,425 ft. Approximately 550 ft of 24-in. cast-iron pipe were laid in Mountain St. East from Burncoat St. to West Boylston St. While this work was being done by contractors, the Water Department crews were laying some 10,000 ft of 16-in., 20-in., and 24-in. reinforcing mains from the Summit towards the city.

On October 28th, just eleven weeks after construction was started, and after the plant had been tested for four days, Mr. Allen turned it over to the Water Department.

After all this effort had accomplished a most remarkable feat of construction, the fall rains came in such quantity that no pumping was needed. However, the station was operated for two weeks anyway.

This first station had three 4-stage centrifugal pumps, rated for 2 mgd against a head of 550 ft, made by the Alberger Pump Co. It was found that one pump would deliver 3 mgd, 2 pumps about 5 mgd, and 3 pumps between 6 and 7 mgd. The pumps were installed in a deep pit, as the water in the reservoir was

low, and were belt-driven by motors located above the high-water mark.

Where the 30-inch pipeline passed through privately owned property to cross under the Worcester-Nashua Railroad, temporary easements were taken for a year. These easements are still being used, and annual rentals are paid to the owners, although some of the properties have changed hands several times.

The station was used again in 1915 for a period of only two weeks, and then in 1917 it was dismantled, and the building removed. It was rebuilt in 1923 and used in 1924, 1925, 1926, and in 1930 and 1931, and was then dismantled.

In the fall of 1941 it again became necessary to take water from Wachusett. A new building was erected on the site of the original pumping station. The three belt-driven pumps were installed, as in the past. In addition, two new Dayton-Dowd pumps were purchased and installed. This necessitated the construction of two more suction lines. The station operated from October 30, 1941, to February 4, 1942.

In 1945, Wachusett Reservoir filled for the first time in several years, and as most of our equipment was below the high-water level, it had to be removed. With the filling of Quabbin Reservoir, it became unlikely that Wachusett would be lowered more than 15 ft from high water, which meant that our pumps could be set above the high-water mark if and when needed again. Consequently, all the old building on the lower level was removed, and the old belt-driven pumps, motors, belts, starters, transformers, etc. were sold. The next year, the suction lines were raised above the high-water mark and capped, and the pump pits were filled with gravel.

The station was again placed in operation in 1949. The building was enlarged somewhat, so that it now encloses the discharge main header as well as the pumps. The building is wood frame, covered with novelty siding, with a tar and gravel roof. A third pump, similar to the two obtained in 1941, was purchased, and all three were set on concrete bases just above the high-water mark.

The equipment now consists of three Dayton-Dowd, or Peerless, pumps, rated at 2.5 mgd against a head of 550 ft, direct-

connected to General Electric induction motors of 300 hp, operating at 2,200 volts. Each unit has a G. E. magnetic switch and a G. E. drum controller. Each pump case is connected to a vacuum system, operated by a Nash Hytor pump. Chlorine is introduced to the suction intake of the pump, the amount being regulated by an Everson chlorinator, manually set for the required rate. A Venturi meter measures the flow.

The only trouble experienced with the present set-up was an occasional tripping of a magnetic switch. Excessive heat was caused by a combination of overloading a motor and the summer sun on a black, flat-roofed, low-ceilinged structure, with insufficient ventilation. With the reservoir nearly full, the head on the pump was enough lower than the head for which the pump was designed, so that the pump overloaded the motor. This was temporarily remedied by partially closing the gate valves on the discharge lines, so that the motors were not overloaded, and by installing large floor-type electric fans to circulate the air in the building.

This station was used in the falls of 1950 and 1953. In the summer and fall of 1955, one unit was operated to maintain pressure in the High Service System, although there was plenty of water in the Worcester reservoirs.

In 1956, Pine Hill Dam, which is a concrete structure, was given a surface-repair treatment, and the reservoir was practically emptied. The spring 1957 run-off failed to fill it by 1,200 mil gal. This condition, followed by a record dry summer, made it necessary to go to Wachusett again. This station was operated from the middle of August until December 27th, and 874 mil gal of water were pumped into the High System. The water cost $80.00 per mil gal. The power cost, including the demand charge for eleven months following shutdown, was $58.00 per mil gal. The cost per kilowatt-hour came to 23.6 mills. Labor, chlorine and other costs amounted to $2.50 per million, making the total cost $140.50 per mil gal. When this is compared with the $20.00, which is the cost of water from our own reservoirs at the point it enters the system, it is rather expensive water.

However, the city is very fortunate to be in a position to obtain such a supply when needed, on such short notice. The

Metropolitan District Commission and its engineers have been most helpful, and their cooperation is sincerely appreciated. Table 1 presents data on the water pumped from the reservoir of the M.D.C. from 1911 to 1957.

TABLE 1.—WATER PUMPED FROM THE METROPOLITAN RESERVOIR

| Year | Dates | Days | Gallons | Price per mil gal |
|---|---|---|---|---|
| 1911 | Oct. 24 to Nov. 11 | 19 | 62,470,000 | $29.00 |
| 1915 | Nov. 1 to Nov. 18 | 18 | 46,800,000 | 29.00 |
| 1923 | Nov. 20 to Nov. 30 | 10 | 38,000,000 | 40.00 |
| 1924 | Nov. 1 to Dec. 23 | 53 | 240,000,000 | 40.00 |
| 1925 | Jan. 1 to Feb. 24 | 55 | 251,800,000 | 40.00 |
| 1925 | July 1 to Dec. 31 | 184 | 690,500,000 | 40.00 |
| 1926 | Oct. 4 to Nov. 27 | 55 | 258,600,000 | 40.00 |
| 1930 | July 22 to Dec. 31 | 163 | 873,200,000 | — |
| 1931 | Jan. 1 to Jan. 15 | 15 | 73,100,000 | — |
| 1941 | Oct. 30 to Dec. 31 | 63 | 426,600,000 | 90.00 |
| 1942 | Jan. 1 to Feb. 4 | 35 | 277,700,000 | 90.00 |
| 1949 | Oct. 12 to Dec. 31 | 81 | 425,000,000 | 40.00 |
| 1950 | Jan. 1 to Dec. 5 | 134 | 785,300,000 | 40.00 |
| 1953 | Sep. 3 to Nov. 27 | 71 | 206,760,000 | 80.00 |
| 1955 | July 13 to Oct. 29 | 109 | 291,100,000 | 80.00 |
| 1957 | Aug. 16 to Dec. 27 | 134 | 874,030,000 | 80.00 |

## SUPER HIGH SYSTEM

As far back as 1915, plans were made for a third water system, to serve the highest hills in West Tatnuck and the northern part of the city. Construction was not started until 1921, when a 12-in. cast-iron main was laid in Pleasant and Bailey Streets to the top of Howland Hill. This is the highest point in the city and is located at the junction of Worcester, Leicester and Paxton. A covered concrete reservoir of 50,000-gal capacity was constructed here at an elevation of 1,050. A small pumping station was built on Pleasant St., and water was transferred from the High Service System to the Super High System.

This served until 1940, when the system was greatly expanded under W. P. A. projects. The Howland Hill Reservoir was enlarged by 200,000 gal, the total storage becoming 250,000 gal. A new pumping station was built on Tory Fort Lane. This

system has been extended so that now it not only serves West Tatnuck and the Airport, but also reaches eastward to Moreland Street Heights, Winter Hill and the Brattle St. area.

The pumping station was designed to be in keeping with houses in the residential area in which it is located. There are two 1,000-gpm pumps, driven by 150-hp motors, and one 200-gpm pump with a 40-hp motor. The pumps are designed to operate against a 395-ft head. The intake is from the 48-in. Low Service main. The station is fully automatic, the pump operation being controlled by the depth of water in the Howland Hill Reservoir. All controls are by Builders.

There is also a connection to the fire-alarm telegraph system, so that a loss of power at the station, or either too high or too low water in the reservoir, is immediately noted in the Fire Department's alarm station on Park Ave. The operator there notifies our Yard Office.

The system has a pressure slightly higher than that in the system of the town of Holden, and is connected to it in a meter vault on Holden St. at the town line. Holden has served us several times when we had trouble on our line. Last fall, when Holden's supply was critical, our system served a section of Holden having about 275 homes, for a period of several months.

This system delivered 84,437,300 gal in 1957 at a power cost of $51.00 per mil gal. The cost per kilowatt-hour was 23.7 mills.

### Beaver Brook Pumping Station

As the city expanded to the north and west, the demand on the High Service System grew to be greater than the supply. Therefore, in 1927 a pumping station was built on Chandler St. near Beaver Brook, for the purpose of transferring water from the Low Service System to the High Service. The station was built by Stone & Webster and has a capacity of 6 mgd. There are two units, each consisting of an Allis-Chalmers pump, rated at 2,100 gpm against a head of 144 ft, directly coupled to a General Electric induction motor of 100 hp operating at 440 volts.

In 1945, the original transformers and starting equipment with open bus bars were replaced with a single transformer and Cabinetrol units by General Electric. The installation of electric

clock-controlled switches permitted automatic operation. The savings in payroll paid for the installation in less than two years.

This station is also connected to the fire-alarm telegraph system, and the operator at headquarters is warned if the electric power fails.

Since 1955, this plant has been kept on a stand-by basis for emergency operation only.

### Quinapoxet Pumping Station

Although the completion of Pine Hill Reservoir in 1924 increased the total storage capacity by over 90%, the city had already started looking for an additional supply for the future. A State commission had been studying the question of an increased water supply for the Metropolitan District Commission, and for Worcester, for several years. In 1923, it recommended taking the Ware, Swift and Millers Rivers. Worcester was well represented on this commission, which in 1926 presented a plan calling for a reservoir on the Ware River at Barre Falls. This would have furnished Worcester with a gravity supply sufficient for 50 years. This failed to pass the legislature, and the compromise bill which was adopted allowed Worcester to pump water from the Quinapoxet River. While the original bill had certain restrictions on the amount of water that could be taken, these have been removed by subsequent legislation, so that the city now has the right to all waters of the Quinapoxet River above a point at or near elevation 708. For these rights, the city paid the Metropolitan District Commission the sum of $1,000,000.

The development of this supply was started in 1930. A natural pond had been enlarged by the construction of a small dam many years ago, for the production of ice. This property was taken by the city, and a pumping station was constructed. The building was located so that it was immediately available for taking water from the existing pond, as well as from the reservoir to be constructed later.

There are two pumping units. Each is a Warren pump, rated for 7,700 gpm against a head of 141 ft, directly coupled to a Fairbanks-Morse synchronous motor of 350 hp, operating at 2,200 volts. The pumps are primed by means of a Nash vacuum

pump. A Venturi meter measures the flow of water, which then passes through a 36-in. steel pipeline about three miles long into Kendall Reservoir.

The construction of the dam and reservoir in 1952 and 1953 was described in a paper read to this Association on February 18, 1954, by Charles E. Cannon* of the firm of Metcalf & Eddy. The total cost of this development to date has been approximately $2,750,000.

In 1957, Quinapoxet furnished 2,647.73 mil gal, or about 32% of the city's total consumption. The power cost was $8.38 per mil gal. The cost per kilowatt-hour was 15.1 mills.

### Westwood Hills Pumping Station

In the fall of 1934, the city took over the property and operation of a small installation, which had been made by a real estate developer to supply a few houses on the top of a hill in an exclusive residential area. The pumping station is a concrete vault set into the side of a hill. It contains two 1½-in. Deming Muller pumps, each driven by a 5-hp motor. Each pump has a capacity of 100 gpm and discharges into a 1,000-gal pressure tank from which a 4-in. supply main runs to the top of the hill. The suction is from a high-service main. A Brummer twin-cylinder air compressor keeps compressed air in the top of the pressure tank. The entire operation is automatic. Although the station is checked every day, twice in the past 16 years the controls have failed, and the 14 customers have received compressed air instead of water. This can be most disconcerting, as the air is mixed with very rusty water.

This is a very small operation, as the station handles only two or three million gallons a year, but the troubles that go with it exceed those of the larger plants. The revenue from the water sold does not cover the cost of operating the station, but the cost of connecting this area to the Super High System would be excessive.

### Olean Street Pumping Station

The ever increasing demand for water on the High Service System reached the point where it could not be adequately satis-

*This Journal, 69:2, 119, June, 1955.

fied by the supply from Lynde Brook Reservoir, together with the 6 mgd being transferred from Low to High at the Beaver Brook Station. At periods of peak consumption, some areas were without water for several hours a day.

In July, 1949, the firm of Metcalf & Eddy was engaged to review the problem and to submit recommendations and cost estimates. The means proposed for remedying the situation called for the construction of a new pumping station near the Holden Reservoirs, a transmission main from here to the northern part of the city, and the erection of three steel distributing reservoirs. The estimated cost was $1,270,000.00, exclusive of land damages.

The proposal was approved by the city, and the engineers prepared plans and specifications. It was decided to proceed immediately with the construction of the standpipe on Millstone Hill and the necessary connections, but to defer the balance of the proposed construction until the Quinapoxet Reservoir project was completed. The Millstone Hill tank was 80 ft in diameter and 40 ft high, with a capacity of 1.5 mil gal. The overflow was about 5 ft lower than Lynde Brook Reservoir. It was erected by Pittsburgh-Des Moines Co. and was placed in service in July, 1951.

It was not until November, 1954, that contracts were signed for the construction of the pumping station, transmission mains, and steel reservoirs on Indian Hill.

The pumping station was located a short distance below Holden Reservoir #2 on the Worcester side of the Worcester-Holden line.

A 30-in. cast-iron line had been constructed about 1902 from Holden #1 Dam through the Holden #2 Basin, to keep the water supply free from contamination during the construction of the #2 Dam. Since this line was no longer in service, it was put to use as the suction main for the new pumping station, advantage being thereby taken of the higher elevation of Holden #1. As flow tests made in 1949 had shown that the Hazen-Williams coefficient was down to about 60, a contract for cleaning and lining was let to the Centriline Corp. After this work had been done, a test showed that the carrying capacity of the line

had been more than doubled. A suction connection to the 48-in. main from Holden #2 was also provided for emergency use.

The transmission mains consisted of 14,450 ft of 36-in. steel pipe and 6,000 ft of 30-in. steel pipe. The pipe was $\frac{5}{16}$ in. thick, lined with coal-tar enamel, wrapped, and in 40-ft lengths, joined with Dresser couplings. The contractor was Johnson Bros. of Auburn, Mass., and the pipe was made by Bethlehem Steel Co.

Two covered steel reservoirs, similar to the one on Millstone Hill, were erected on Indian Hill by the Pittsburgh-Des Moines Co. These tanks were 90 ft in diameter and 26½ ft high, with the overflow about a foot higher than Lynde Brook Reservoir. The two tanks have a total storage capacity of 2.3 mil gal, and the connections are so arranged and gated, that either may be removed from service for repairs.

The connections were a 16-in. cast-iron main down the north side of the hill to the existing distribution system, and a 24-in. cast-iron main down the south side to the steel transmission mains and to the existing mains in New Bond St. and West Boylston Drive. A check valve in the 16-in. line prevents flow into the tanks from the north. An altitude valve and telemetering controls are in a pit on the 24-in. line. These connections, the tank foundations and the pumping station were constructed by the R. H. White Co. of Auburn, Mass.

The pumping-station building is of first-class construction, with steel frame, reinforced-concrete floor, brick and tile walls, concrete slab and slate roof. An overhead traveling crane and hoist facilitates the handling of heavy equipment. The chlorine-equipment room and the chlorine-tank room are isolated from the pump room and have individual entrances from the outside.

Unit #1 is a Warren pump with a rated capacity of 2,100 gpm at a head of 100 ft, coupled directly to a 75-hp Westinghouse motor, operating at 2,300 volts.

Unit #2 is identical to Unit #1.

Unit #3 has a rated capacity of 4,200 gpm at a head of 120 ft and is connected to a 150-hp motor.

Unit #4 has a rated capacity of 10,500 gpm against a head of 150 ft. It is directly coupled to a 500-hp wound-rotor motor, arranged for three-speed operation.

The water level in the Indian Hill Reservoir is measured, recorded and controlled by the following method:

A 1-in. pipeline from each of the tanks is carried to an underground chamber at the northerly end of Hockanum Way. The water pressure in this 1-in. line actuates, through a mercury manometer tube, an electrically controlled transmitter. The signals are transmitted to the Olean Street Pumping Station through a leased telephone line. The receiver and control unit at the station records the water elevation and operates pumps Nos. 1, 2 and 3 on a pre-set cycle for both rising and falling water elevations in the reservoir.

A Venturi meter records the rate and amount of pumping. Unit #4 is operated by manual control of electrical switch gear only. The chlorinating equipment and the telemetering, as well as the Venturi, are by Builders. The electrical switch gear is by Clarke. The building has automatic oil-fired hot-water heat and manually controlled, electrically powered ventilators.

This station also is connected to the fire-alarm telegraph headquarters, and a signal is relayed there in the event of a power or pump motor failure, excessive high or low water in the Indian Hill Reservoir, or excessive high or low temperature in the building.

The total cost of this project to date is approximately $1,500,000.

During 1957, this station pumped 2,219,165,000 gal of water at a power cost of $8.68 per mil gal. The cost per kilowatt-hour was 21.87 mills.

## Summation

Worcester has pumping capacity at Quinapoxet, equal to the average daily consumption of the entire city. The new Olean St. station has a capacity of more than 15 mgd, or more than the average daily consumption on the High System. With Pine Hill usage held to an amount not exceeding an average year's runoff, there should not be much need for further emergency pumping. However, it is nice to know that Wachusett is still nearby.

# MICROSTRAINING AND OZONATION—PILOT-PLANT INVESTIGATIONS FOR TREATING A SURFACE-WATER SUPPLY AT DANVERS, MASSACHUSETTS

BY ELSON T. KILLAM*

[*Read March 20, 1958.*]

The water supply for the town of Danvers, Mass., comprises a surface supply, drawn from Middleton Pond, Swan Pond and Emerson Brook.

Middleton Pond has a small watershed (1.36 sq mi), with 386 mil gal of available storage, providing a high storage ratio of 283 mil gal per sq mi. The original supply from Middleton Pond has for many years been supplemented by storage in Swan Pond, lying approximately 4,000 ft west of the western end of Middleton Pond. Swan Pond has a negligible watershed (only 0.2 sq mi), with 120 mil gal of available storage, or a storage ratio of 600 mil gal per sq mi. This water is pumped as required and when available to Middleton Pond.

Following a dry period in 1949, which reduced residual storage in Middleton Pond to a critical level, the capacity of the supply was still further increased by diversion of Emerson Brook, with a tributary watershed of 4.3 sq mi. A pumping station was constructed at the site of a small diversion dam, and a force main was laid to deliver this supplemental supply to Middleton Pond during the period between November and June each year.

Treatment is limited to coarse screening, fluoridization, pH adjustment with lime, and chlorination. The water is very soft and of excellent chemical quality, with an average residue on evaporation of 44 ppm, chlorides 4 ppm, hardness 16 ppm, and alkalinity 9.6 ppm.

The watershed is sparsely inhabited, and from the standpoint of purity as measured by absence of pollution, the supply is of desirable quality. The principal objection to the quality of the Danvers supply is color, which generally varies between 40 and

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90 ppm, or several times higher than the average color of Massachusetts supplies, and is particularly noticeable to consumers accustomed to filtered water.

Furthermore, as with most surface supplies taken from natural ponds, the periodic development of various microorganisms has resulted in some objections from the standpoint of taste and odors, although this problem has in general been effectively controlled by treatment in the pond. Objections have also periodically been raised due to the presence of fine particles of sediment passing through the system.

The State Department of Public Health conducted experiments in 1927 on both slow sand filters and filters loaded with ferric hydroxide, and at that time it was stated by Mr. Thorpe, then consultant to the Water Board, that: "It is absolutely safe to say that filtration of one of the above described types will provide a water of excellent quality when using the combined supply, i.e., Middleton Pond and Emerson Brook." It was then estimated that the cost of slow-sand type filters of 3-mgd capacity, together with low-lift pumps and other appurtenances, would be $130,000, with the cost of rapid sand filters estimated at approximately $90,000.

In 1938 experimental coagulation tests were made and plans prepared for a rapid sand filtration plant with a capacity of 3 mgd and an estimated cost of $145,000. An application for Federal funds was approved by the government, but when the project was submitted in a referendum it was not approved by the town.

In 1948 the Welsbach Corp. set up its mobile pilot plant at Middleton Pond, to study the effect of ozone treatment on color, taste and odors. Although the pilot plant was small, the work was carefully conducted, with approximately 100 test runs over a period of three months, and with initial color varying from 55 to 70 ppm. The application of ozone varied from 1 to 10 ppm. In some of the tests high dosages were applied, for the purpose of obtaining a residual as an alternative to supplemental chlorination.

The reports indicated that with an initial color of 55 ppm, the application of 2 ppm of ozone resulted in a treated-water

color of 22 ppm, and the application of 4 ppm of ozone resulted in a color of 10 ppm.

At that time the estimated cost of ozone facilities, based upon application of 7 ppm for 1.5 mgd, with an ozone-generating capacity of 88 lb per day, and with an installation of four 25-lb ozonators, was reported to be approximately $72,500. It was also estimated that the average energy consumption for generating and applying ozone, including air compressing and drying, would be 12 to 14 kwh per lb of ozone produced. With an average dosage of 4 ppm, on the assumption that the concentration of algae and microorganisms was kept under control, this would represent a total consumption of approximately 425 kwh per mil gal, and with power at 1-¾¢ per kwh, the electrical cost of ozone treatment was then estimated at $7.44 per mil gal.

In view of the effectiveness of color reduction with ozone and the apparent low cost of construction and operation, as compared to rapid sand filtration, data relative to the earlier ozone water-supply installations at Whiting, Ind., and the large project then under construction at Philadelphia were reviewed, and serious consideration was given to this alternative. It was recognized, however, that the ozone treatment would not solve the problem of sediment, and it was furthermore felt that it would be advantageous to await the development of operating data and costs at the Philadelphia plant before arriving at a decision on this matter.

Primarily as a result of a paper read before this Association several years ago, we became interested in microstraining as a possible supplement to ozone, by providing, in addition to the color removal effected by ozone, a method of reduction of microorganisms and sediment.

As a result of various conferences, the town arranged to conduct a series of tests at Middleton Pond, using both ozone and microstraining. The necessary equipment was installed, the ozone facilities being furnished by the Welsbach Corp. of Philadelphia and the microstraining unit by Glenfield & Kennedy, Inc., through their local representative, G. R. Evans. The period of testing extended from July 13 through November 31, 1956.

As in all pilot-plant operations, various objectives were

introduced, involving tests to explore possible maximum ranges of operation in order to establish performance under variable loadings.

In further conformity with the usual pilot-plant operations with a temporary set-up of piping, valves, pumps and equipment, various interruptions not to be anticipated with permanent full-size units were encountered. Under such conditions it is inevitable that the test data reflect conditions which would not prevail in normal routine operation, and accordingly it is logical to assume that after the development of experience in the operation of full-scale equipment, results would be obtained reflecting appreciably higher efficiencies than indicated by the complete listing of all variables recorded during the tests (see Fig. 1).

## Microstrainer

### *Description*

The microstrainers, comprising a rotary drum screen, are very similar in appearance to vacuum filters. Microstraining involves the use as a filtering medium of a very finely woven fabric of stainless steel mesh, which is capable of matting on the surfaces thin "schmutzdecke," which, with the fabric support, have very high flow ratings at low hydraulic resistance and are capable of retaining suspended solids of sizes still smaller than those of the already minute apertures in the fabric.

Three fabrics have been used. The Mark O, the finest, has approximately 160,000 apertures per sq in., the Mark I 80,000, and the Mark II 58,000. The Mark O fabric was used in the tests.

The mesh-encased revolving drum used in the tests was submerged to approximately 60% depth in a containing tank, with raw water entering the interior through one end and passing outward through the rotating mesh. A row of spray jets was located along the top of the drum, to dislodge deposited material on the drum interior as it passed the top of the rotation. This backwash was caught in a trough suspended at the top of the drum and carried to waste.

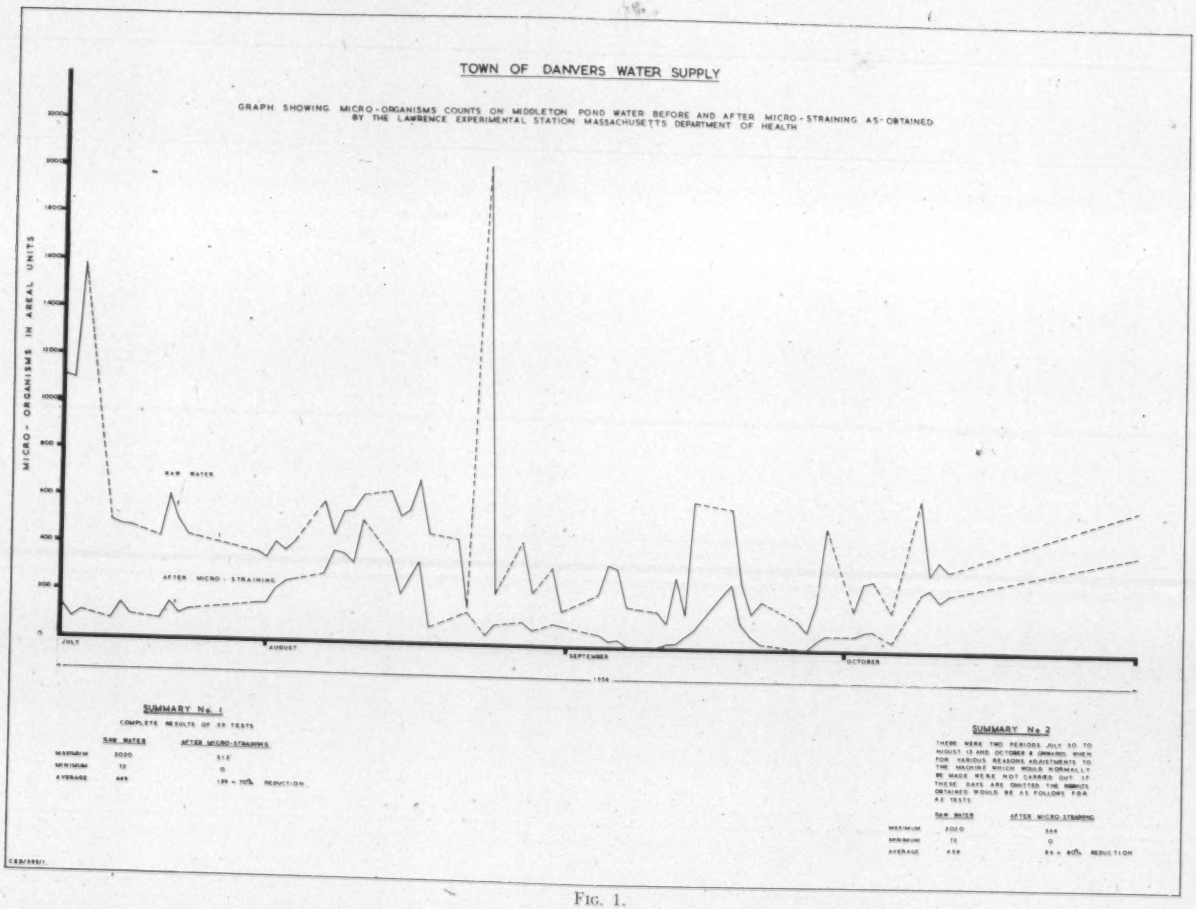
TOWN OF DANVERS WATER SUPPLY
GRAPH SHOWING MICRO-ORGANISMS COUNTS ON MIDDLETON POND WATER BEFORE AND AFTER MICRO-STRAINING AS OBTAINED BY THE LAWRENCE EXPERIMENTAL STATION MASSACHUSETTS DEPARTMENT OF HEALTH
MICRO-ORGANISMS IN AREAL UNITS
RAW WATER
AFTER MICRO-STRAINING
JULY
AUGUST
SEPTEMBER
OCTOBER
1936
SUMMARY No. 1
COMPLETE RESULTS OF 39 TESTS
RAW WATER
AFTER MICRO-STRAINING
MAXIMUM 2020 512
MINIMUM 12 0
AVERAGE 449 139 = 70% REDUCTION
SUMMARY No 2
THERE WERE TWO PERIODS JULY 10 TO AUGUST 15 AND OCTOBER 6 ONWARD WHEN FOR VARIOUS REASONS ADJUSTMENTS TO THE MACHINE WHICH WOULD NORMALLY BE MADE WERE NOT CARRIED OUT. IF THESE DAYS ARE OMITTED THE RESULTS OBTAINED WOULD BE AS FOLLOWS FOR 42 TESTS.
RAW WATER
AFTER MICRO-STRAINING
MAXIMUM 2020 164
MINIMUM 12 0
AVERAGE 439 88 = 80% REDUCTION

FIG. 1.

*Screen Loadings*

The test unit was 2 ft 6 in. in diameter and 2 ft 0 in. long, with a submerged area of 10 sq ft. The test flow varied from 98 to 161 gpm, averaging 132 gpm, with consequent loadings of 10 to 16, averaging 13.2 gpm per sq ft.

Operating procedures were purposely varied, but average operations involved a drum speed of 1.5 rpm, peripheral travel of 11.8 ft per min, a head loss of 3.6 in., and a backwash of 8.9% of the raw-water volume at 20 psi pressure. A large proportion of the backwash volume discharged against the screen was recovered as screened effluent, with a net waste of approximately 2.8%

*Screen Efficiency*

The unit reduced average suspended solids from 4 ppm in the raw pond water to 2.6 ppm (36%), reduced average microorganisms (total standard units) from 438 to 86 (80%), and reduced amorphous matter from 234 to 119 (49%).

In relation to the removal of microorganisms, it is of interest to note that removal of *asterionella* varied from 20% to 100%, averaging 85%, while the removal of the other most prevalent type during the tests—namely, *cosmarium*—varied from 15% to 96%, averaging 45%.

*Backwash Waste*

An analysis of the waste water, carrying off the material deposited on the screen, indicated an average of suspended solids of 23 ppm, with 82% volatile; microorganisms of 2,700 total standard units and an average amorphous matter of 290.

*Ozone Unit*

Test facilities for ozone treatment included an ozone generator, producing ½ to one pound of ozone per day, an air compressor, and a diffusion column 18 ft high and 6 in. in diameter. The rate of flow through the column averaged 4.7 gal per min, with a detention of 5.6 min and a velocity of 3.2 ft per min.

The total air supply applied to the base of the column and introduced against downward flow averaged 0.36 cfm, or 0.077 cu ft per gal. The flow through the diffusion column was equivalent to 29 sq ft per mgd, and the air supply equivalent to 50.3

cu ft per min per mgd. The air pressure at the compressor averaged 8 psi.

The color of the pond water during the series of tests varied from 58 to 75, averaging 65 ppm. The color of the water after ozone application varied from 70 to 40, depending upon the ozone dosage which was set in various tests, ranging from as low as 1.7 ppm to as high as 15.3 ppm, averaging 8.5 ppm.

The application of ozone to pond water with an average color of 65 and final color, on the basis of selected normal tests, after preliminary runs and adjustments was as follows:

| Final color | Ozone application (ppm) |
|---|---|
| 35 | 2.0 |
| 30 | 3.0 |
| 25 | 4.0 |
| 20 | 5.0 |
| 15 | 6.5 |
| 10 | 8.0 |

The ph of the raw water averaged 6.7. After ozone application the pH range varied from 5.6 to 6.9 and averaged 6.1. With the application of 5 ppm of ozone, the pH was generally lowered from an initial value of 6.7 to a value after ozone treatment of 6.2.

Laboratory analyses indicated that aeration of the effluent from ozone treatment restored the pH to approximately the raw-water value and created a further reduction in odor intensity. Odors in the water before ozone application included vegetable, grassy and earthy classifications. Odor after ozone application included vegetable, grassy and pungent. The average odor intensity was 2.1 before and 1.4 after ozone treatment.

## Microstraining and Ozone Facilities as Applied to the Danvers Problem

In recent years the consumption in Danvers has been subject to wide variations, with increasing ratios of maximum month, maximum week and maximum day with respect to annual average consumption. For this reason, in the application of this equipment to this specific problem, variable capacities were assigned

to different units, depending upon the convenience of future expansion.

The units under consideration included the following:

*Microstraining*

Three microstrainers, 7 ft 6 in. in diameter by 5 ft long, with Mark O fabric, 1½-hp motors, peripheral speeds adjustable up to 100 ft per min (4.25 rpm).

This would involve a structure approximately 46 ft long, 15 ft wide and 7 ft 6 in. deep below floor grade, providing space for three initial units plus one additional future unit.

*Ozone*

Ozone equipment included one diffusion tower, approximately 18 ft in diameter and 20 ft high; three 60-lb generators; three compressors, each 90 cfm; one air cooler for 240 cfm, and one air dryer for 240 cfm. The layout also included two aerators, each 7 ft wide, 14 ft long and 10 ft high, and treated-water storage 32 ft by 32 ft by 6.5 ft deep.

The space requirements for the ozone generators and appurtenances vary considerably with alternative types and arrangement. Space available in the pumping station of approximately 24 ft by 36 ft, or 860 sq ft, was considered adequate for such equipment.

## Summary

The microstraining units are well constructed of selected materials, with indicated low maintenance and operating costs accompanying very slow speeds and low power requirements.

The test unit demonstrated effective reduction of suspended material and the more prevalent type of organisms, all of which is in line with the reported operating results of extensive installations in England, where this type of equipment has been used for more than 10 years. The early installations were primarily for pretreatment in advance of slow sand filters, to increase filter capacity. In more recent years, the use has been expanded, and it has been recently reported that a total of approximately 100 units is in service with variable purposes, including pretreatment ahead of slow sand filters, pretreatment ahead of rapid sand

filters, and as the sole means of filtration of both public and industrial supplies. Nine units are in service in connection with sewage and industrial-waste clarification.

The application of ozone has been found entirely practicable and effective in reducing color to any desired amount. The performance and power requirements for production of ozone have been established in many years of operation at municipal water plants at Whiting and Philadelphia, and at numerous industrial installations. This method has a wide range of flexibility, and any anticipated variation in raw-water color can be handled, and any desired effluent color—at least down to 10 ppm or lower —can be readily secured.

It is evident that in installations where filtration is unnecessary from a standpoint of watershed pollution and the objective of filtration is primarily color removal and sediment and organism reduction, this alternative treatment, because of relatively low cost of construction and operation, wide flexibility, and economical expansion of capacity, deserves careful consideration.

The tests were arranged by Daniel McFadden, Town Manager, with microstrainer test unit and supply pump furnished by Glenfield & Kennedy, Inc., and the ozone equipment furnished by Welsbach Corp. The plant was operated by the Water Department, Vernon Russell, Superintendent, with Mr. Karonis in full-time attendance, assisted by my associate, Roland L. Wood. Mr. Evans of Glenfield & Kennedy and Mr. Colyer of Welsbach Corp. furnished valued suggestions in set-up and operation.

Tests on the site were supplemented by extensive analyses and coincident valued assistance by the State Department of Public Health from their nearby Lawrence Experimental Station.

# HISTORY AND OPERATION EXPERIENCES WITH WEST SPRINGFIELD WATER DEPARTMENT

BY CARL M. JACOBSON*

[*Read April 17, 1958.*]

In the late 1800's the town of West Springfield, Mass., was served by private water companies. The principal one, The West Springfield Aqueduct Co., was bought out by the town, when it set up the municipal supply in 1892.

The original source of supply was the Darby Brook Reservoir, commonly known as Piper Reservoir. It had a drainage area of slightly more than a third of a square mile and a capacity of about ten million gallons. It was used for water supply until 1948, but in the later years it was used to supply only the Boston & Albany Railroad. After 1948 it was turned over to the Park Department for recreational purposes. In the flood of August, 1955, the dam was topped and failure occurred.

Shortly after the town took over the water system, a proposed development of Bear Hole Brook, by the construction of a 300-mil gal reservoir, having a safe yield of about a million gallons daily, was studied and recommended. However, no positive action was taken. When you think of engineers in 1895 recommending a project of this size for a town with a population of approximately 6,000, you can see that they looked forward to providing for a town that would develop quickly with a good water supply.

Shortages of water following the turn of the century resulted in the first development of Bear Hole Brook by the construction of a low dam, filter and pumping station, together with another reservoir farther up the brook. The present Bear Hole Filter Plant is constructed on the same site, and the remains of the dam are now in the reservoir. This was put into service during 1907-1908, and the line used to pump to the 1-mil gal tank, near the site of the present 4-mil gal tank, is still in service.

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The million-gallon tank was torn down in 1956 after approximately 50 years of service. This was an open top, wrought-iron tank, built and erected by the Walsh Boiler Works of Holyoke. For the service it performed and the small maintenance that had been done, this was in good condition, but to place a roof on it would cost too much for the storage retained.

The Bear Hole Reservoir was raised twice, until it contained about 57 mil gal and had a surface area of approximately 17 acres. The Filter Plant and Pumping Station were also improved and enlarged upon from time to time. At the time of the August 19, 1955, flood these were all destroyed in part or totally by the failure of the dam. This failure did not occur by topping, as in the case of Piper Reservoir Dam, but was due to some failure in the structure or subsoil. It was an earthen dam with timber core, and the earlier raising of it twice with additional cores, accompanied by the torrential rainstorm, may have uncovered a weakness in it.

Bear Hole was and is now designed on a safe yield of 1.5 mgd, but the filtration rate and pumping capacity are figured on approximately 4 mgd. The previous station many times filtered and pumped about 3¾ mgd and the present station will put out 4 mgd, if needed.

Shortages of water throughout the years were prevented by purchasing water from the city of Springfield, from one of their transmission mains that passes through the town. During the flood when our supply collapsed, this was our only source of supply. And to quote Peter Karalekas, Engineer of Springfield Water Department, when informed of our plight, "We might as well sink or swim together." Swim we did. The town was not without water during those trying days when both our sources of supply had failed. By the enlargement and improvements made since 1953, we doubt if we shall need to purchase water in the near future, but will maintain the connections for emergencies.

Constant search and investigation have been carried on to augment the supply of water, ever since the town took over the water supply. Nearly all brooks and drainage areas within the town have been studied as to their possibility of supplying either ground or surface water. Also sources of supply outside of West

Springfield, in Westfield, Holyoke, and as far away as the town of Montgomery, have been studied.

The following statement made by Frank A. Barbour, Engineer to the Board of Water Commissioners in 1937, sums up the results of the many investigations very well:

"Thus from the various efforts to obtain an additional supply during the past 30 years it may be concluded that no source of water of a significant and acceptable quality can be found within the limits of West Springfield, and that the Pond Brook area in Westfield is not available for use:"

At about this time the investigation of Great Brook in Westfield and Southwick began under Superintendent Theodore M. Beach. Test wells were driven and revealed very favorable soil conditions in the vicinity of the Westfield-Southwick line. The tests indicated the presence of a large quantity of ground water of excellent quality, with a hardness almost equal to Bear Hole. Passage of an act through the State Legislature to give West Springfield rights in this location was obtained.

Further testing of the area was carried out and land purchased. In 1946 passage of a bond issue was obtained, with the result that development of wells and the laying of a 16-in. pipeline approximately seven miles long to the Bear Hole Station were started. Two 12-in. gravel-packed wells were put in to a depth of approximately 40 ft, and a 19-day test was run on these, delivering approximately one million gallons per day each, with very small draw-downs observed. The return of groundwater table took place within 24 hours after pumping ceased. The estimated drainage area of the field is about 23 sq mi, and proven capacity of the field between 8 and 9 mgd.

When I took over as Superintendent from Theodore Beach in 1952, he had two of these wells in use and the third ready to be connected to the system. The wells were equipped with 10-hp pumps and motors with a low discharge head, providing approximately 1 mgd apiece. In times of high demand the rate would drop in proportion to the friction loss, with the result that approximately 2½ mil gal were delivered to the clear-water well at the filter plant. From here it was repumped to the Roger Ave. tank and distribution system. The Southwick Well Field solved

the water shortage before the high-lift pumps, but the recurring problem of a small storage after pumping and the frictional losses in undersized mains for the growth of the town developed to a more acute stage. The study of this had begun while the well field was under development. A more detailed study was undertaken in late 1952 by Tighe & Bond, Consulting Engineers, Holyoke, Mass. The result of this study was a $1,300,000 expansion program that was voted on in the spring of 1953.

Coming into the department about two months before the retirement of the Superintendent and getting adjusted to a new system and town in the middle of a construction season are difficult enough, but when you add finishing-up of a well field and investigation of expansion program both in supply and distribution, and then, to top it off, you lose one-third of your filter capacity by a bank failure on the filter beds during the peak season, you become discouraged. With the help of loyal and long-term employees the Department went ahead and into the expansion program.

In August, 1955, as the final contracts of the expansion program were being brought to a finish, we were hit by a torrential rainstorm that caused more damage to this department, I believe, than the rest of the town together. In it we lost both sources of supply under water from the weakening of earthen retaining structures. The Bear Hole Filter Plant and Pumping Station was destroyed by failure of our dam about 6 a.m., although during the night water was flowing above the brook banks in the rear of the station and may have caused some damage to filter beds before total failure. To illustrate the force of water as it passed through the station, there was a 2½-ton truck parked outside, which was moved about 300 ft and turned around before being half-buried in the sand. A hydrant at the station, possibly knocked off by the truck, took up a good part of pumping from the well field. When this was cut off the line about five hours later, the tanks due to other pipeline breaks around town had been depleted to about ⅓ of the designed storage. As we could not hold the tanks with the well-field production, and we did not really know what was operating there, because of flooded roads, help was asked from Springfield.

The following morning about 4 a.m., as we worked on one of the major distribution-system breaks, we heard reports that there was danger of the North Pond of Congomond Lakes breaking out. This occurred and flooded the well field and some of the equipment, besides taking out the bridges in the area, including a pipe bridge. Under emergency work conditions we were able to bring back into service 3 million of the 4 million capacity within two weeks. As a result of this flood, many leaks developed in the transmission main, as most of it had been under water at some time.

In October of 1955 we had a second high-water condition, in which we saved the wells by erecting temporary earthen dikes around the stations, and the water came to within six inches of the top.

The department now, with the completion of the reconstruction of the Bear Hole facility, looks forward to being able to meet the demand and has a planned expansion of the well field and transmission main to town ready for the time when it is needed.

# RAISING PLEASANT VALLEY RESERVOIR DAM AT BRATTLEBORO, VERMONT

BY JOSEPH A. KESTNER, JR.*

[*Read May 15, 1958.*]

Brattleboro, Vt., is one of the pioneer towns of the Connecticut River valley and the only Brattleboro on this earth. Brattleboro is popularly referred to as the "metropolis of southeastern Vermont" and "the place where Vermont begins." It is located near Fort Dummer, the first settlement in Vermont, which occurred in the year 1774. Brattleboro derives its name from William Brattle, one of its founders. The town covers an area of approximately three square miles in the geographical heart of New England. It is on the eastern slopes of the Green Mountains, and elevations in Brattleboro range from 310 to 1,760. There are 24 manufacturing establishments, employing 2,000 men and 1,500 women, with an annual payroll of reportedly $8,000,000 per year and a production value of goods of $20,000,000 per year. The industry is diversified and manufactures pocketbooks, organs, optical lenses, wood products, cleaning fluids, machine tools, farm supplies and various other items.

I do not have to tell those who have visited Pleasant Valley Water Supply or those who have toured Brattleboro that this is a progressive municipality. The town water supply is but one evidence of its progressiveness. Prior to 1927 Brattleboro had town and village governments. In 1927, Brattleboro changed to a town form of government and has remained that way since. George F. Miller has been Brattleboro's Town Manager for the past ten years. Justin Holden, former Brattleboro Water Superintendent and Commissioner of Public Works since 1952, has served the town for 33 years.

The water-supply history of Brattleboro parallels that of many other New England communities. It began as a private

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water system in 1881, by the diversion of spring water to the present 3-½ mil gal Chestnut Hill distribution reservoir. The spring source was gradually outgrown. Some years later the supply was increased by pumping water from West River with a stream-driven pump to the Chestnut Hill reservoir. Both sources were outgrown in the early 1900's.

In 1907 George E. Crowell, owner of the Brattleboro Water Works Co., made plans to expand the system, and Pleasant Valley Reservoir was mentioned as an important part of the future water supply. The site had been selected a few years previous to 1907, and 80 acres in the Pleasant Valley Reservoir area were purchased. Water rights on Stickney Brook, about two miles north of the reservoir, and on Sunset Lake, then known as Marlboro North Pond, as well as water rights on various streams in the locality, were acquired at this time.

Sunset Lake is the most northerly body of water on the Brattleboro system, with a drainage area of 0.6 sq mi and a water-surface elevation of 1,450. Stickney Brook, a natural tributary of West River, is diverted into the Pleasant Valley Reservoir watershed. Its source is in Sunset Lake, and with its tributaries it has a drainage area of three square miles, exclusive of the Sunset Lake watershed. An intake dam on Stickney Brook, about 1.9 miles downstream from the outlet of Sunset Lake, diverts water from this area through 10,000 ft of 12-in. main to Pleasant Valley Reservoir. The reservoir itself has a drainage area of 1.16 sq mi. Thus at the Pleasant Valley Reservoir dam the total watershed area is 4.76 sq mi.

In 1907 a 16-in. pipeline was laid from Pleasant Valley Reservoir to West Brattleboro, and the following year it was extended farther into Brattleboro proper. One must admit that this was a progressive water-supply development for private enterprise to build in the year of 1907.

A newspaper article in the Vermont *Phoenix* of September 3, 1909, indicated that experts of that day considered the water supply sufficient to meet the needs of a city of 50,000 persons. This was based on an incorrect watershed area of 15 sq mi. The article indicated that the average consumption of water at the time was 60 gal per day for every man, woman and child, but

that to be conservative the design for the Pleasant Valley Reservoir was based on 100 gal per day per person, and it indicated that once Pleasant Valley Reservoir was filled, it would supply Brattleboro's 8,000 people for 100 days, or more than three months, even though no water ran into the reservoir. The article stated, "It would seem that this Reservoir would give an inexhaustible supply for both domestic and public use including fire protection." It served the needs of Brattleboro well for a period of 45 years, and its original planners knew that the future capacity of Pleasant Valley Reservoir could be 120 mil gal. However, the reservoir constructed in 1909 with a lower dam held the capacity at spillway elevation 620.5 to 80 mil gal.

I mentioned previously that the development of this supply was conceived about 1905. Work first began about 1907, at which time a controversy over the question of municipal ownership of the water system arose. Construction operations were suspended until the municipal ownership plan failed. The same question of municipal ownership occurred in the year of 1899 but on neither occasion became a reality. With municipal ownership a dead issue, the Brattleboro Waterworks Co. undertook construction of the original Pleasant Valley dam in 1909. It is reported that 500 lb of dynamite were used, and excavation totalling 10,000 cu yd was necessary for the construction. The dam was approximately 650 ft in length. It varied in height from 30 ft to 4 ft along the corewall, which extended to solid rock throughout its entire length. At the lowest point the corewall was 10 ft in width, and the earth fill on the upper and lower sides of it was at an angle of 45°. These earth slopes would probably gray the hair of present-day soil experts. The dam required approximately 40 tons of cement; the gravel used was taken from areas on the dam site, and the sand was obtained from a farm a short distance away. The construction cost was reportedly $40,000. The reservoir and 16-in. transmission main, constructed about 1909, served Brattleboro successfully for 45 years.

In 1953 a second, 16-in. cement-mortar-lined, cast-iron transmission main, generally parallel to the original line with a total length of 17,300 ft, was constructed at a cost of $206,500. This transmission main was provided to maintain pressures during

heavy use and to eliminate Brattleboro's dependence on a single transmission main for water supply. The old and new transmission mains have frequent valved interconnections, to insure a dependable supply at all times.

During 1953, Brattleboro had a very dry summer and fall. It became necessary to supply Pleasant Valley Reservoir with water from Sunset Lake. The normal rainfall for the months of June, July, August and September is about 16 in. for the Reservoir area. During these four months in 1953 it was only one half of this amount. The dry spell continued until October 28, during which time the available water in Sunset Lake became exhausted when the lake level fell below the outlet pipe. During mid-October, 1953, the minimum runoff from the entire watershed of 4.76 sq mi was approximately 450,000 gal per day, or only 92,000 gal per day per sq mi. Though there was no critical water shortage in Brattleboro, town officials were aware that the supply must be increased.

A study was made of possible reservoir sites along Stickney Brook, upstream from Pleasant Valley Reservoir. A particular effort was made to locate a site upstream from the Stickney Brook intake dam, because it has a watershed nearly three times that of the Pleasant Valley Reservoir. Full use is not made of the runoff to the Stickney Brook intake, because it is limited by the capacity of the 12-in. diversion main connecting the Stickney Brook intake with the inlet of Pleasant Valley Reservoir. Due to the steep slope of Stickney Brook, a relatively high dam would be required for reasonable water storage, and no economical site for a reservoir was found above Pleasant Valley. The studies indicated that raising the height of the Pleasant Valley Dam was by far the most economical additional water storage. Preliminary studies indicated that 50 to 60 mil gal of storage at a cost of $150,000 to $175,000 could be provided by raising Pleasant Valley Reservoir water level ten feet. Preparation of contract plans and specifications for the proposed work was promptly authorized.

To raise an existing dam, the first step is to study the original construction drawings. If there were any plans for the original dam, none could be found. Fortunately, Mr. Holden had preserved

photographs of the original construction and obtained a lengthy newspaper editorial from the Vermont *Phoenix* of September 3, 1909, describing the dam and its construction with considerable technical detail. The article included the length of the dam, variations in height and thickness of the corewall, and the fact that it rested on rock, material sources and other useful information. It gave the upstream and downstream earth slopes as 45°. This article plus the half-dozen photographs were the only sources of information on the existing dam.

As Pleasant Valley Reservoir was the only source of water supply for Brattleboro, the quality had to be maintained during new construction. This meant that large quantities of earth fill could not be deposited along the upstream face of the dam, because such an operation would make the water turbid. The construction method had to be one that would leave the upstream face of the original dam relatively undisturbed. This eliminated the possibility of raising the corewall ten feet vertically and placing earth embankment along both faces.

The second proposed plan was a cantilever-type retaining wall just downstream from the corewall. This plan required fill along the upstream face. A one-on-one embankment slope was necessary, to avoid depositing considerable fill in the water. To overcome steep embankments and maintain water quality, the earth embankment and paved-face dam was designed (see Fig. 1). There were definite advantages in this type of construction. It offered the best means for making a water-tight joint between the existing corewall and the new construction. It placed a minimum load on top of the existing corewall, which was known to be of concrete without any reinforcement. The paved-face plan was similar in cost to the cantilever retaining-wall type of construction, but eliminated the objectionable features.

The reservoir area was planted in the early 1930's with white pine. There was a substantial growth of good timber by 1953 below the proposed water line. Before new construction got under way, a logger was engaged to do the cutting. The upper part of each tree, where the space between branches was 14 in. or less, was sold to the logger for $2.00 per ton, and he transported and sold it in a nearby area for bucket stock. The lumber from the

logs was salvaged for town use. The beautiful knotty-pine walls in the Town Garage offices are a small part of the salvaged lumber. Town maintenance crews burned the brush and scraps from the lumbering operations during the winter months.

The contract for the project was awarded by competitive bidding to F. A. Tucker, Jr., of Rutland, Vt. The official starting date was July 13, 1954. Albert Spencer was Resident Engineer for Barker & Wheeler, Consulting Engineers, and Paul Trudeau was Construction Superintendent for Mr. Tucker.

The dam has several interesting construction features, which I shall briefly describe.

The spillway on the original dam had a length of 21 ft and was capable of discharging about 122 cfs, or approximately 105 cfs per sq mi. The new spillway has a crest length of 87 ft 10 in., and it is capable of discharging about 1,500 cfs, or about 1,300 cfs per sq mi. Its capacity is about ten times that of the original spillway. The new spillway channel was proportioned for the spillway design flow, and in sections where it was not excavated in rock, the floor of the channel is paved with grouted riprap, to prevent erosion.

The material for the dam embankment was obtained from a borrow area on the east side of the reservoir. It was a bank-run gravel with some loam content and good compaction qualities. It was necessary to pass all the fill material through a grissly or coarse bar screen, to eliminate the many stones larger than five inches in maximum diameter.

The contract required that the entire borrow area be excavated at not less than five feet below spillway surface, in order not to leave any shallow-water areas to promote algae growths.

The embankment for the dam was placed in layers not exceeding seven inches in thickness after rolling and was compacted by a sheepsfoot roller. Provision was made for a light wetting of the embankment material during placement, to keep the moisture content at an optimum level for good compaction.

The existing dam had a 16-in. cast-iron outlet pipe and a 24-in. blow-off line leading from the intake tower through the embankment and corewall. The earth embankment for the raised dam would increase the fill over these pipelines by more than

20 ft, and these mains were enclosed in a reinforced-concrete encasement from the existing corewall to the toe of the new embankment. The excavation for this encasement came at one of the deepest parts of the existing corewall, and it was necessary to expose the old corewall for a vertical height of about 30 ft. This provided our only first-hand look at the existing corewall with its "stepped-in" construction. Needless to say we breathed easier when the embankment was replaced immediately following the encasement of the outlet pipelines.

Near the toe of the original dam, about 100 ft on each side of the intake structure, there were two springy areas on the face of the downstream embankment. These were investigated by hand excavation during construction, and the leakage was carefully observed. We concluded there was no major channel of leakage through the old embankment. The two spring areas were backfilled with crushed stone and piped through the toe of the new embankment with six-inch cast-iron pipe and a small headwall at the outlet end. The amount of leakage from these two locations has not increased since the dam was raised.

During the course of construction two cracks were found in the top of the corewall, as it was uncovered. These were excavated on the downstream face but disclosed no major water leakage. Wedge-shaped pieces of concrete were poured, to form a buttress and seal the corewall cracks.

One of the most unusual features of the dam is the joint between the old corewall and the new paved face (see Fig. 1). A great deal of thought was given to means for making a watertight joint between the old corewall and the new paved slope. It was finally decided that this could best be accomplished by first cutting a slot about 1½ in. wide along the entire 650 ft of the old corewall at a uniform depth of four inches. A concrete saw was rented for this purpose. The saw rental was only a nominal $18.00 per day, but the blades cost about $75. apiece. We thought the cost of blades would far surpass the machine rental, but the double cut for the 1½-in.-wide slot was made along the entire length of the corewall with only two blades, one of which was not completely worn out. A ⅛-in. by 8-in., stainless-steel, type 302, mill-rolled and annealed, soft strip was placed in the slot. The

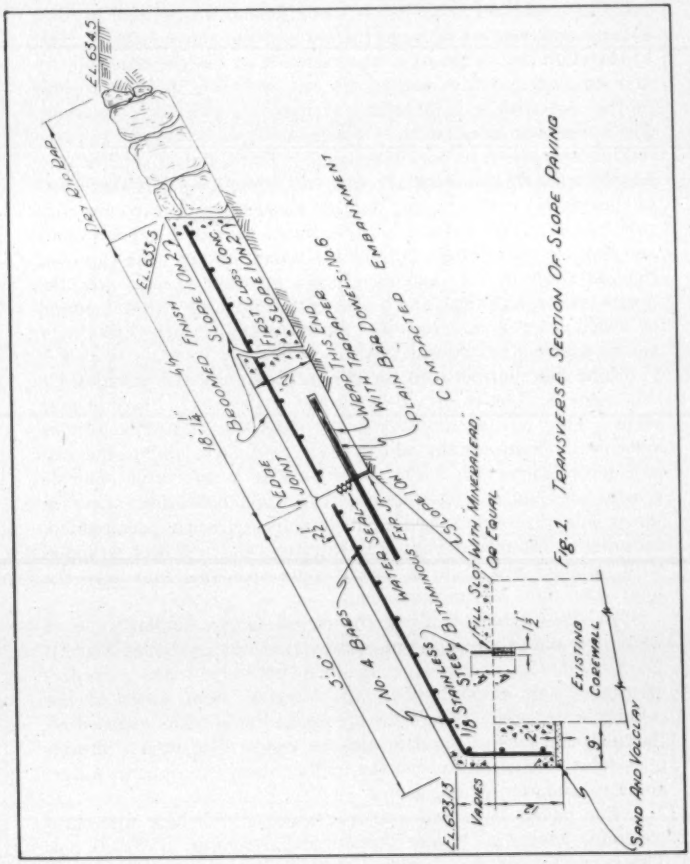


Fig. 1. Transverse Section Of Slope Paving

stainless-steel plate came in 12-ft lengths and was welded to form a continuous barrier between the old and the new concrete. Half of the eight-inch-wide strip was fastened in the old corewall, by first supporting it with packed dry jute and then filling both sides of the slot with a sulphur-base water-pipe jointing compound. The upper four inches of the stainless-steel plate was cast in place on the cap portion of the slope paving. The stainless steel proved excellent for this purpose. It was stiff enough so that there was no danger of crushing while pouring concrete, as is the case with soft copper. The welding of the plates provided a continuous and durable water stop. For further watertightness, the cap over the old corewall was extended down at least a foot over the upstream corewall face, and underneath this, sand with one pound of Volclay per square foot was placed in a two-inch-thick layer before pouring the corewall cap.

The junction between the corewall cap and the paved slope was made flexible, to provide for some settlement of the embankment. This was accomplished by placing a three-rib cellular water-seal longitudinally along the paved face, where the cap and paved slope join. The water-seal is a polyvinyl chloride plastic of cellular construction, to permit deflection. On the under side of the water-seal a half-inch by four-inch, premoulded, bituminous expansion joint was inserted, and a dowel wrapped with tarpaper was used, to permit some movement but keep the joint watertight and in alignment.

At 75-ft intervals along the paved face a similar type of waterstop and expansion joint construction was used (see Fig. 2). To provide for expansion, one-inch by three-inch, pressure-creosoted, soft wood lumber was inserted along sides of the cellular water-stop. Where the creosoted lumber was exposed on the upstream face of the dam, the space was filled with a bituminous joint compound, to seal the lumber from exposure to water, and ice formation in the winter.

The paved slope was constructed of 12-in.-thick first-class concrete, having a 28-day compressive strength of 3,500 psi. The concrete was transit-mixed, and air-entraining cement was used for all concrete exposed to the weather. The 12-in.-thick slope pavement was reinforced with ½-in. deformed bars on

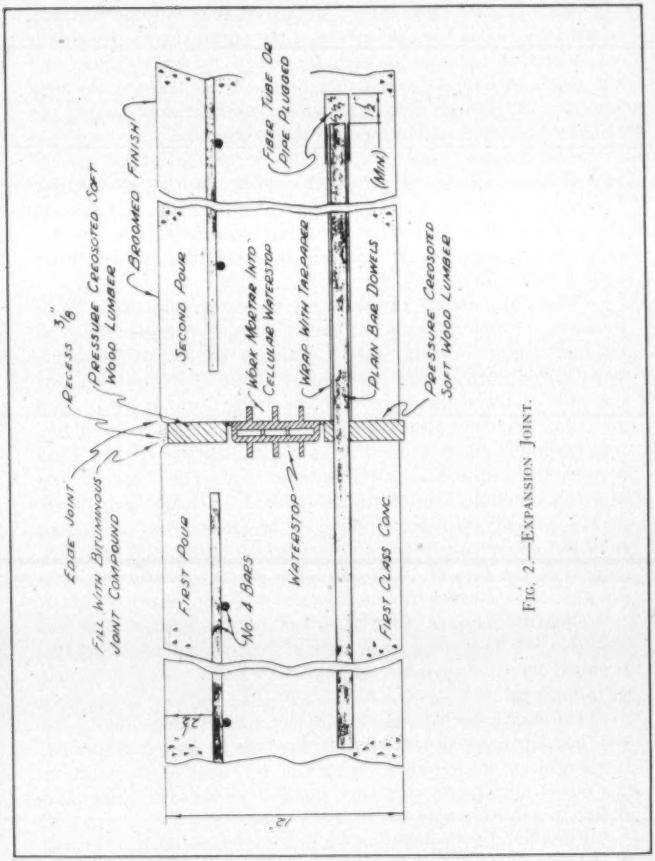


FIG. 2.—EXPANSION JOINT.

eight-inch centers each way. The face of the reinforcement was located 2-½ in. below the surface of the paved slope. Dry riprap was placed in the area between the top of the embankment and the upper edge of the paved slope. To date no leakage has been observed through the new embankment, and the slope paving has remained in place without any visible settlement.

The original wood structure on top of the intake was removed and used as the engineer's office during construction. Valve-stem extensions were provided for the existing valves in the intake, and outdoor valve stands were provided. One new 16-in. valve was placed in the raised intake, to permit drawing water from a higher level.

The downstream embankment face was topsoiled for a thickness of four inches, and was strip-sodded horizontally on ten-foot centers. There is still evidence of the strip-sodding. Vertical sod gutters were provided at about 23-ft centers across the face of the embankment. These were made saucer-shaped and three feet in width to provide drainage. The strip-sodding was pegged in place to hold it on the embankment. The areas between the strip-sodding were topsoiled to a depth of four inches, raked horizontally and fertilized with 7-7-5 (Nitrogen, phosphorus, potash fertilizer), applied at the rate of 2 lb per 100 sq ft in the upper two inches of the topsoil. Grass seed was then applied at the rate of 10 lb per 1,000 sq ft, consisting of 40% timothy, 30% clover, 20% redtop and 10% domestic rye grass.

Construction cost of the 60 mil gal of additional storage was $123,889.59. This is approximately $2,000 per mil gal of storage. It raised the total present capacity of Pleasant Valley Reservoir to 140 mil gal.

The entire project was a pleasant undertaking. The town and the contractor cooperated fully from the beginning to the end. If all projects during an engineer's career went as smoothly as this one, I am certain engineers would have few gray hairs and all live to a ripe old age.

From humble beginnings as a private enterprise in 1881, the Brattleboro water supply has successfully served its citizens. It became a municipal system in 1924 after several unsuccessful public attempts to purchase the private system over a period of

35 years. It was acquired by the village of Brattleboro at a cost of $525,000. The water system became town-owned in 1927 during consolidation of the village of Brattleboro with the town. Today the system has an original cost of $1,433,717 and a net book value of $1,086,200. The present bonded indebtedness of Brattleboro water system is $386,000.

# LAKE WHITNEY SANITARY CONDITIONS IN RELATION TO CERTAIN LABORATORY EXAMINATIONS

BY S. JACOBSON* AND E. L. MacLEMAN†

[*Read September 15, 1958.*]

Water works frequently are confronted with the task of maintaining sanitary conditions on their watersheds. Where there is scarcity of habitation and the outright ownership of a large percentage of the area, supervision may be fairly simple. There is now, and probably will continue to be, increased pressure for the release, either by development or by relaxation of control, of areas which in the past have provided a high degree of protection for water supplies. As more acreage is developed, the problems of maintaining a usable supply of water may become increasingly difficult.

The maintenance of sanitary conditions on watersheds by water utilities and the enforcement of Health Department ordinances by local and state sanitarians provide water in as near a natural state as possible. All water-works operators are familiar with the greater effort required, the more a surface water deviates from its natural state. The difference in cost between merely adding chlorine as a protective measure and such additional treatment as coagulation, sedimentation and filtration is an important economic factor. In the past, it was a simple matter to abandon a water requiring costly treatment in favor of more suitable sources which were available.

A program of laboratory control for untreated surface water is helpful in evaluating sanitary conditions, finding violations and assisting in the elimination of these violations at an early stage. In dealing with highly polluted waters, attempts to base conclusions on one type of analysis have been fairly successful. However, for potable water supplies, the variations are so slight in many cases and the possible variables so numerous, that results

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must depend on combinations of physical, chemical, bacteriological and microscopic analyses (3), (14), (19).

For water-plant operators there are other ways in which watershed sanitation through laboratory analysis can be of value. Determination of the agricultural, domestic or natural sources of eutrophication‡ of lakes could assist in controlling their biological balance. As discussed by Hasler (8), eutrophication either natural or artificial, unless controlled, may not only limit, but eventually completely eliminate, the use of a body of water as a source of drinking water. Where there are no apparent signs of violations, particularly in surface supplies containing nutrients of non-sewage origin, large algal populations may develop. Adequate and timely treatment with copper sulfate is usually employed to prevent the tastes, odors and turbidities or the reduction in filtration rates and runs caused by algae. Also the development of remedial measures to eliminate the sources would be desirable.

Lake Whitney, located in Hamden, Conn., just north of New Haven and the oldest source of supply for the New Haven Water Co., is an excellent example of a reservoir for an intensive study. To obtain a potable supply, the water company owns the entire shoreline of the reservoir and much of the land along the tributaries, and in addition treats the water by slow sand filtration and chlorination. Present practice for Lake Whitney is to attempt to control algae through application of copper sulfate as required.

The Lake Whitney watershed is the only one in Connecticut with a public sewerage system. A sewered area of 1.8 sq mi delivers to the New Haven treatment plants, while the sanitary requirements of the remaining 35.9 sq mi of watershed must be satisfied by means of subsurface drainage. The geology of the watershed is comprised mainly of Triassic arkose or sandstone overlain by a Pleistocene mantle of stratified drift and till, with a few areas of dolerite intrusive (1). Such a stratum will generally provide excellent treatment by subsurface drainage. However, it is well established that the conversion of organic matter into inorganic nutrient elements increases algae growths in receiving waters (19). Agricultural drainage, while not predominant, is also a factor that must be given consideration.

‡Fertilization.

## Procedures

The chemical and bacteriological analyses used in this study depended on their relationship to domestic waste, possible significance in algae development, and suitability for routine analysis. All analytical procedures were in accordance with *Standard Methods for the Examination of Water and Sewage,* 9th Edition, unless otherwise indicated. The Most Probable Number of coliform bacteria per 100 ml (MPN) was determined by serial dilution, the Brilliant Green Lactose Bile Broth being used for confirmation. Chemical tests included nitrite nitrogen (N), nitrate nitrogen (N) by the phenoldisulfonic acid method, chlorides (Cl) by the Mohr method, sulfates ($SO_4$) by the barium chloride method with a Hellige turbidimeter, soluble orthophosphate ($PO_4$) by stannous chloride method, pH, alkalinity (as $CaCO_3$), and acidity (as $CO_2$). Microscopic examinations for algae were based on standard areal units per 0.5 ml.

The following list includes all stations (see Figure I) at which one or more samples were taken:

1. Lake Whitney—Dam
2b. Lake Whitney—Country Club Bridge
2d. Lake Whitney—Webb Brook Culvert
3. Lake Whitney—Waite St. Bridge
4. Pine Swamp—Treadwell St. Bridge
4b. Pine Swamp—Putnam Ave. Bridge
6. Shepard Brook—Dixwell Ave.
6b. Shepard Brook—Turner's Pond
7. Mill River—Whitney Ave. Bridge
8. Mill River—Ives St. Bridge
9. Mill River—Mt. Carmel Ave. Bridge
9b. Eaton Brook—Whitney Ave. Bridge
9c. Willow Brook—Willow St. Bridge
9d. Mill River—Old Lane Road Culvert

The six stations selected were those which it was felt would provide sufficient data. Lake Whitney is little more than an enlarged river (see Fig. I), a fact which made the choice of the Dam, the Country Club, and Waite St. logical. Mill River samples collected at Whitney Ave. provided a control on the

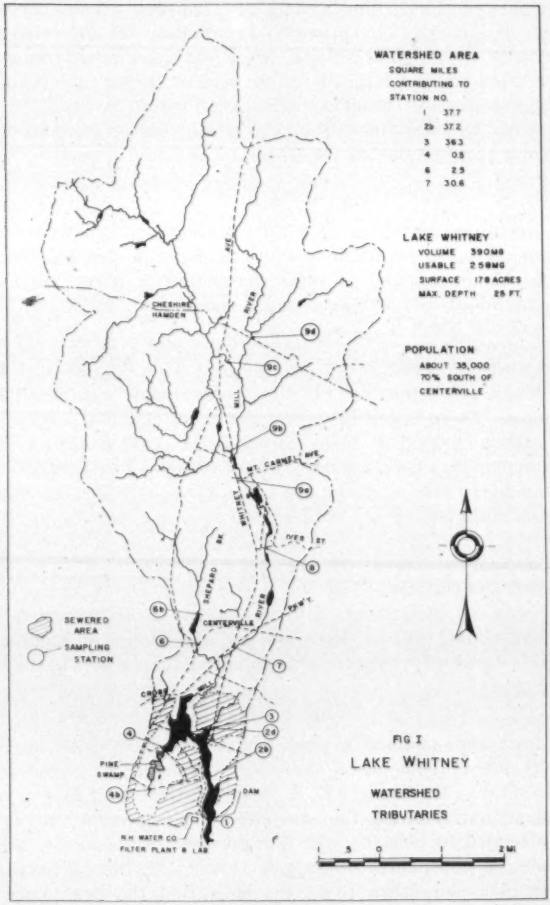



FIG I
LAKE WHITNEY
WATERSHED
TRIBUTARIES

principal tributary. Pine Swamp at Treadwell St. and Shepard Brook at Dixwell Ave. provided information on the remaining tributaries with significant drainage. Additional sampling at the other listed stations indicated those selected to be representative and adequate. All samples taken were within a depth of one foot, with the exception of the Dam which was obtained from the intake, a cross section of the upper 10 ft.

## Discussion of Data

An inspection of the data for the entire period showed that in general most favorable conditions for the development of certain algae occurred at water temperatures above 60°F. A comparison of the averaged data above and below 60°F. is presented in Table 1.

### *Microscopic Analyses*

Algae are dependent on direct autotrophic assimilation of nutrients. There is general agreement upon nitrates, phosphates, and carbon dioxide as being essential (5), (11), (17). Their development has been correlated with changes in pH, alkalinity and acidity. Temperatures are critical, with each alga having its own optimum range, while sunshine is a necessity for most algae.

During the period of this study all observed algae were recorded and counted. Only the genera *Anabaena, Clathrocystis, Scenedesmus, Pediastrum, Asterionella* and *Synedra* which had sufficient counts will be discussed and are shown in Figures II and III. Over-all totals are illustrated on the curves at the end of the paper.

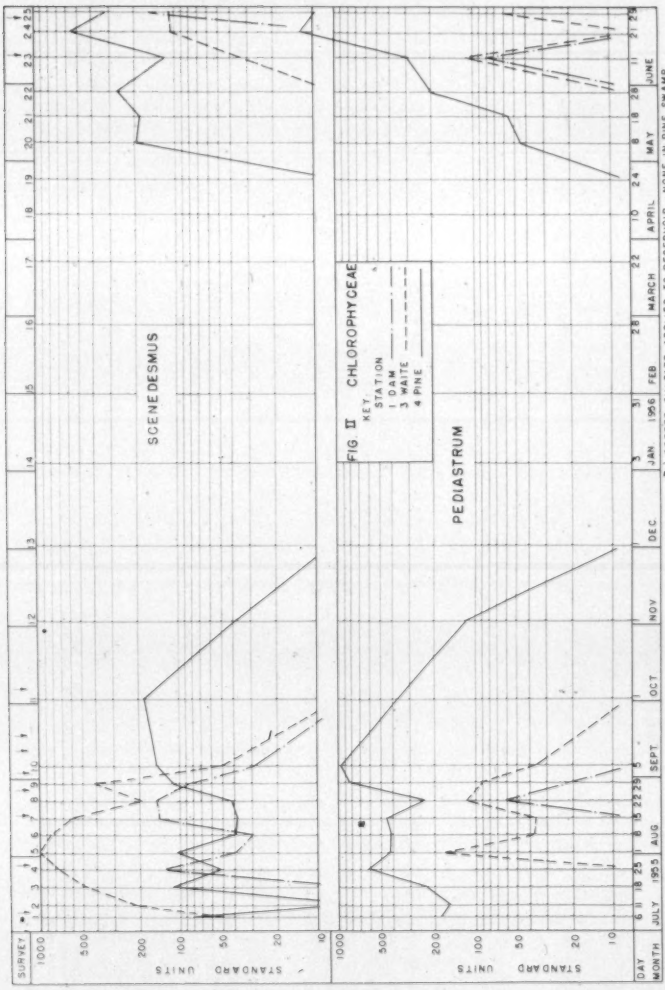
### *Cyanophyceae*

*Anabaena* attained a peak count of 52,000 s.u. in Pine Swamp late in July, when the water temperature ranged from 79° to 83°F. (see Table 2). A smaller growth of *Clathrocystis* varied similarly during the same period. The variation of the bloom tended to coincide with the phosphates; however, a late increase in phosphates could not revive the bloom once the temperature had fallen to 69°F., indicating the preference of these *Cyanophyceae* for water temperatures above 70°F.

TABLE 1.—AVERAGE PERIOD VALUES OF OBSERVATIONS FOR LAKE WHITNEY AND ITS TRIBUTARIES
July 6, 1955 — June 29, 1956

| Station no. | ppm | | | | | | | pH | | Standard units per 0.5 ml | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $NO_3$ | $PO_4$ | Cl | $SO_4$ | Alk. | Acid. | MPN | min. | max. | Cyano-phyceae | Chloro-phyceae | Diatom-aceae | Total std. un. |
| Temperatures > 60° F. (14 Surveys) (Avg. Flow at Dam, 39.2 mgd) (Avg. Sunshine, 9.9 hr a day) | | | | | | | | | | | | | |
| Reservoir | | | | | | | | | | | | | |
| Dam (1) | 0.60 | 0.09 | 4.7 | 10.1 | 47.3 | 3.04 | 65 | 7.0 | 8.6 | | 66 | 161 | 258 |
| Club (2b) | 0.55 | 0.03 | 4.6 | 9.5 | 45.6 | 2.22 | 242 | 7.0 | 8.9 | 19 | 121 | 32 | 195 |
| Waite (3)* | 0.40 | 0.07 | 6.1 | 10.7 | 52.4 | 1.44 | 427 | 7.2 | 9.3 | 272 | 393 | 47 | 762 |
| Mill River | | | | | | | | | | | | | |
| Whitney (7) | 1.03 | 0.09 | 4.1 | 9.2 | 45.9 | 3.91 | 7,300 | 7.1 | 7.5 | | | | |
| Ives (8)** | 0.73 | 0.11 | 3.8 | 9.4 | 43.2 | 3.87 | 4,915 | 7.2 | 7.5 | | | | |
| Mt. Carmel (9a)** | 0.80 | 0.14 | 3.5 | 10.2 | 40.6 | 3.53 | 4,123 | 7.2 | 7.5 | | | | |
| Shepard Brook (6) | 1.45 | 0.13 | 5.0 | 12.2 | 41.3 | 2.97 | 11,450 | 7.2 | 8.8 | | 26 | 226 | 407 |
| Pine Swamp (4) | 0.09 | 0.05 | 14.3 | 13.5 | 68.8 | 9.45 | 1,590 | 6.9 | 7.3 | 4,490 | 746 | 4 | 6,090 |
| Temperatures ≤ 60° F. (11 surveys) (Av. Flow at Dam, 91.5 mgd) (Avg. Sunshine, 6.7 hr a day) | | | | | | | | | | | | | |
| Reservoir | | | | | | | | | | | | | |
| Dam (1) | 0.94 | 0.03 | 4.5 | 9.7 | 37.2 | 3.23 | 274 | 6.9 | 7.5 | | | 34 | 43 |
| Club (2b)† | 1.03 | 0.04 | 4.2 | 9.2 | 36.8 | 3.14 | 424 | 6.8 | 7.5 | | | 23 | 62 |
| Waite (3) | 1.09 | 0.03 | 4.3 | 9.2 | 37.8 | 2.74 | 1,230 | 6.9 | 7.8 | | | 17 | 30 |
| Mill River | | | | | | | | | | | | | |
| Whitney (7) | 0.83 | 0.03 | 3.5 | 8.1 | 33.5 | 2.83 | 1,205 | 6.9 | 7.3 | | | | 10 |
| Shepard Brook (6) | 2.01 | 0.05 | 3.6 | 9.7 | 26.4 | 2.60 | 945 | 6.8 | 7.3 | | 99 | 234 | 420 |
| Pine Swamp (4) | 1.82 | 0.02 | 17.4 | 15.4 | 57.1 | 8.01 | 1,070 | 6.8 | 7.2 | | | | |

*Samples not taken for first three surveys.
**Samples collected at these stations for first 10 surveys only.
†Two samples not taken because of ice.


SCENEDESMUS
PEDIASTRUM
STANDARD UNITS
1000
500
200
100
50
20
10
SURVEY
DAY
MONTH
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
1955
1956
FEB
MARCH
APRIL
MAY
JUNE
KEY
STATION
1 DAM
3 WAITE
4 PINE
FIG II CHLOROPHYCEAE
* COPPER SULFATE APPLIED TO RESERVOIR - NONE IN PINE SWAMP

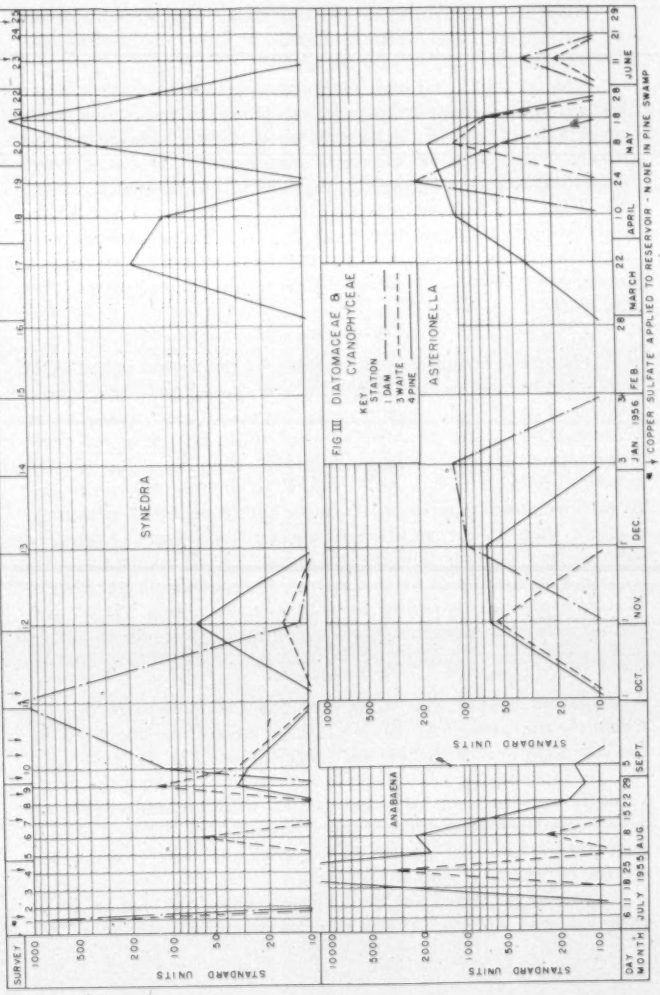


FIG III DIATOMACEAE & CYANOPHYCEAE
KEY STATION
1 DAM
3 WAITE
4 PINE
SYNEDRA
ASTERIONELLA
ANABAENA
STANDARD UNITS
SURVEY
DAY
MONTH
JULY 1955
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN. 1956
FEB.
MARCH
APRIL
MAY
JUNE
COPPER SULFATE APPLIED TO RESERVOIR - NONE IN PINE SWAMP

Although influent nitrates as high as 4.5 ppm were observed, the low nitrate concentrations shown in Table 2 indicate consumption of this chemical by the algae.

The occurrence of high phosphates, with low nitrates at the peaks of the *Cyanophyceae* counts, seems to indicate a more complete utilization of the nitrates when sufficient phosphate was present. Later high nitrates with inadequate phosphates, lower temperatures and less sunshine resulted in less growth.

*Cyanophyceae* showed the same preference for alkaline water as noted by other investigators (6). These organisms were unable to bloom in the reservoir, due to lower alkalinity or to a greater sensitivity to copper sulfate, as shown in Figure 3 for *Anabaena*.

### *Chlorophyceae*

The green algae, *Scenedesmus* and *Pediastrum*, occurred in significant numbers at the Dam, Club, Waite St. and Pine Swamp stations. Figure II shows the areal curves of these organisms at these stations. The environment was most favorable for their propagation in Pine Swamp; however, conditions for growth appeared to be more favorable in the lake stations, where the size of each organism was 1½ to 2 times that found in Pine Swamp. Factors such as the addition of copper sulfate and a greater dilution by high flows lowered the counts at the lake stations.

In Pine Swamp as well as at other stations significant counts of *Chlorophyceae* appeared at temperatures above 55°F., and counts were at a maximum when temperatures were above 80°F.

### *Diatomaceae*

Diatom counts were composed for the most part of *Asterionella* and *Synedra*. Both of these organisms appeared in the lake mainly during the cooler periods (see Fig. III).

In Pine Swamp *Asterionella* were recorded when the temperature was between 37° and 60°F., with highest counts at 55°F. Similarly, at the lake stations counts were obtained over a temperature range of 35° to 67°F., with the best growths occurring between 49° and 55° F.

*Synedra* appeared in Pine Swamp when the temperature variation was 41° to 72°F., with maximum growth at 60°F.

TABLE 2.—RELATIONSHIP OF CERTAIN CONDITIONS TO THE GROWTH OF *Cyanophyceae* IN PINE SWAMP

| | 7/18 | 7/25 | 8/1 | 8/8 | 8/15 | 8/22 | 8/29 | 9/5 | 10/1 |
|---|---|---|---|---|---|---|---|---|---|
| Sunshine (avg. hr/day) | 11.6 | 11.7 | 9.0 | 11.8 | 6.1 | 9.2 | 9.7 | 7.7 | 7.8 |
| Temperature (°F.) | 83 | 79 | 79 | 79 | 80 | 79 | 69 | 72 | 65 |
| *Anabaena* (s.u.) | 3,000 | 52,000 | 1,847 | 2,370 | 745 | 175 | 138 | 154 | * |
| *Clathrocystis* (s.u.) | * | 1,036 | 498 | 438 | 280 | 75 | 51 | 141 | * |
| $PO_4$ — ppm | .08 | .12 | .05 | .17 | .00 | .01 | .06 | .01 | .00 |
| $NO_3$ — N — ppm | .08 | .07 | .18 | .00 | .00 | 1.0 | 1.0 | .08 | .05 |
| Alkalinity (ppm) | 82.6 | 78.5 | 75.2 | 76.1 | 65.0 | 44.5 | 50.0 | 57.4 | 58.8 |

*Indicates too few to count.

On the other hand Shepard Brook, the effluent from Turner's Pond, had significant counts when the temperatures were between 64° and 85°F., with the greatest growth at 85°F. This disagreement was probably because Shepard Brook had *S. radians* while Pine Swamp had *S. pulchella*. In the lake stations the temperature range for all *Synedra* was 53° to 81°F., with best growth at 64°F., indicating a mixture of the two species. The peak counts for this organism tended to coincide with the fall and spring turnovers.

The summer growths of diatoms in Pine Swamp were small compared with that of Shepard Brook. This was due in all probability to shading by weeds and competition with other algal growths in the swamp. Diatoms are known to be sensitive to light, too much or too little sunlight hindering growth (19).

*Coliform Bacteria*

The MPN of coliform bacteria is useful in evaluating the sanitary quality of untreated surface water, if proper consideration is given to seasonal conditions, duration of storage, and the significance of coliform bacteria not of sewage origin (16).

At the tributary stations during the period when the water temperatures were above 60°F., the average MPN's varied from 11,450 to 1,590, and in the cooler period they varied from 1,205 to 945, indicating the diluting effect during a period of greater run-off. The effect of storage on average MPN's is well illustrated in the lake stations. During the warmer period there was a decrease from 427 to 65 approaching the dam, while the reduced storage due to increased run-off in the cooler period resulted in a decrease from 1,230 to 274.

Individual observations of MPN's ranged from less than 4.5 to 70,000, showing the sensitivity of this test. Observed high values in a tributary aided in the disclosure of a nearby sanitary violation.

In the reservoir during periods with low flow, especially in warm weather, the self-purification by storage caused a decrease in the MPN's of coliform bacteria and lessened the significance of the coliform test in evaluating sanitary conditions of the watershed. During periods of high flow, the MPN was more significant

of sanitary conditions of the drainage area due to the comparatively small storage capacity of Lake Whitney.

*Chemical Analyses*

*Nitrate Nitrogen*

Nitrate nitrogen is well established as an excellent plant nutrient. It is produced by nitrogen fixation; it is present in commercial fertilizers and is found as an end product in the stabilization by oxidation of organic matter, including, for example, human waste (17). In water analysis high nitrates are generally indicative of past pollution.

In Mill River there was an increase in the nitrate nitrogen from Ives St. to Whitney Ave., probably due to the effect of subsurface drainage in the unsewered area. Mill River with its large watershed proved to be the main source of nitrates, although Shepard Brook, with its much smaller flow, showed a higher concentration due to a sanitary infraction.

An inspection of Table 3 shows a fair correlation between nitrates and flow. The degree of correlation is somewhat obscured by various factors, the main interference being summer algae. There was a general tendency for nitrate values to vary directly with the flow. However, prolonged high flows generally resulted in lower nitrates by flushing action.

The greater portion of nitrate reduction in lakes may be attributed to various forms of aquatic life (5), (10), (11) and was quite evident in this study. It may be well illustrated by using the nitrate and algae figures for Whitney, Waite, and Pine as recorded in Table 1.

At Whitney when no significant algae counts were recorded, the nitrate values were very close for both winter (0.83 ppm) and summer (1.03 ppm). Waite St. clearly shows the effect of the presence of algae. Counts rose from 30 standard units in the winter to 762 in the summer, while the nitrate value dropped from 1.09 to 0.04 ppm. The effect at Pine Swamp is even greater —algae counts rose from 420 to 6,090 standard units, while nitrates dropped from 1.82 to 0.09 ppm.

In considering the summer values, a comparison of the figures obtained at Waite and Whitney also indicates the extent

TABLE 3.—VARIATIONS IN NITRATES AND FLOW

| Survey no. | Date | Avg. flow at dam (mgd) | $NO_3$ — nitrogen (ppm) 1. Dam | 2b. Waite | 7. Whitney |
|---|---|---|---|---|---|
| | *1955* | | | | |
| 1 | 7/6 | 12.6 | 1.00 | 0.40 | 0.70 |
| 2 | 7/11 | 11.1 | 1.10 | 0.34 | 1.20 |
| 3 | 7/18 | 11.0 | 0.40 | 0.10 | 1.80 |
| 4 | 7/25 | 14.4 | 0.60 | 0.08 | 1.50 |
| 5 | 8/1 | 9.9 | 0.25 | 0.20 | 0.95 |
| 6 | 8/8 | 8.2 | 0.07 | 0.03 | 1.20 |
| 7 | 8/15 | 66.8 | 0.30 | 0.65 | 0.75 |
| 8 | 8/22 | 165.0 | 0.80 | 0.30 | 0.90 |
| 9 | 8/29 | 57.5 | 0.45 | 0.45 | 1.00 |
| 10 | 9/5 | 32.8 | 0.40 | 0.35 | 0.60 |
| 11 | 10/1 | 22.6 | 1.20 | 0.40 | 0.60 |
| 12 | 11/1 | 136.2 | 0.60 | 0.30 | 0.20 |
| 13 | 12/1 | 168.0 | 1.10 | 1.70 | 1.80 |
| | *1956* | | | | |
| 14 | 1/3 | 31.1 | 1.62 | 2.03 | 1.60 |
| 15 | 1/31 | 47.7 | 1.74 | 1.24 | 0.96 |
| 16 | 2/28 | 89.4 | 1.23 | 1.34 | 1.03 |
| 17 | 3/22 | 97.5 | 0.75 | 1.54 | 0.58 |
| 18 | 4/10 | 108.4 | 0.75 | 0.74 | 0.72 |
| 19 | 4/24 | 101.6 | 0.69 | 1.07 | 0.69 |
| 20 | 5/8 | 81.9 | 0.80 | 0.71 | 0.28 |
| 21 | 5/18 | 84.5 | 0.48 | 0.77 | 0.68 |
| 22 | 5/28 | 58.5 | 0.56 | 0.53 | 0.53 |
| 23 | 6/11 | 66.1 | 0.51 | 0.80 | 0.80 |
| 24 | 6/21 | 50.2 | 0.42 | 0.70 | 1.06 |
| 25 | 6/29 | 20.4 | 0.87 | 1.09 | 1.27 |

to which algae consume nitrates. The areal counts rose from too few to count to 762 standard units, while the nitrates dropped from an average of 1.03 ppm at Whitney to 0.04 ppm at Waite. Pine Swamp, where influent nitrate values were as high as 4.5 ppm, had an average value of 0.09 ppm and produced 6,090 standard units of algae in the effluent.

Graphs of the analyses of samples of water collected at six stations are presented in Figures IV to IX.

*Chlorides*

Chloride concentrations in surface waters normally vary with the proximity to the sea and are fairly constant in a particular area. They are of sanitary significance when affected by animal or human wastes.

In Mill River the average concentration of chloride at temperatures greater than 60°F. increased from 3.5 ppm at Mt. Carmel to 4.1 ppm at Whitney Ave. and finally to 6.1 ppm at Waite St. At lower temperatures due to greater dilution, the chlorides were somewhat lower in Mill River, increasing from 3.5 at Whitney Ave. to only 4.3 ppm at Waite St. Thus, the variation from normal chlorides for all stations on the watershed was slight, with the exception of Pine Swamp which was affected by agricultural drainage and discontinued tile fields. Pine Swamp samples showed an average chloride content of 14.3 ppm when the water temperature was high and algae were flourishing, as compared with an average of 17.4 ppm at lower, less favorable temperatures.

Although relatively lower chlorides in Pine Swamp were accompanied by high algae counts, the use of chloride through direct assimilation was not apparent. The presence of substantial concentrations of chlorides in the relatively cleaner water of the other stations, which did not support an algae bloom, indicates that other factors were of greater significance. The chlorides, due to the relatively high normal value and the lack of sensitivity, were generally inadequate as indicators of sanitary conditions on this watershed. Even in Shepard Brook, where a sanitary infraction was observed, the chloride increase was not as evident as the increase in MPN and nitrates at the time the trouble occurred (see Table 4).

*Sulfates*

The sulfate content of a surface water is dependent upon the geology of the area and added wastes, including laundry wastes and the end products of sewage oxidation (4), (13).

In Mill River and the reservoir, the concentration of sulfates did not appear to vary significantly. The variation of average values ranged from 8.1 to 10.7 ppm throughout the study. In

TABLE 4.—SHEPARD BROOK SANITARY INFRACTION

| Date | 7/6 | 7/11 | 7/18 | 7/25 | 8/1 | 8/8 | 8/15 | 8/22 | 8/29 |
|---|---|---|---|---|---|---|---|---|---|
| MPN | 240 | 700 | 7,000 | 70,000 | 620 | 24,000 | 24,000 | 2,300 | 620 |
| $NO_2$ — N, ppm | — | — | 0.015 | 0.038 | 0.030 | 0.040 | 0.010 | 0.010 | 0.009 |
| $NO_3$ — N, ppm | 0.90 | 0.30 | 0.80 | 1.80 | 1.10 | 3.00 | 0.90 | 2.50 | 1.90 |
| $PO_4$, ppm | — | 0.0 | 0.12 | 0.20 | 0.40 | 0.10 | 0.00 | 0.06 | 0.00 |
| Cl, ppm | 5.7 | 6.2 | 6.8 | 5.8 | 7.1 | 4.9 | 5.5 | 5.5 | 1.0 |
| $SO_4$, ppm | 10.7 | 12.7 | 12.2 | 10.4 | 11.0 | 15.0 | 19.7 | 15.1 | 12.6 |
| Acidity, ppm | — | 0.00 | 0.00 | 3.08 | 3.87 | 5.19 | 2.96 | 2.99 | 3.26 |
| Alkalinity, ppm | 48.0 | 46.8 | 40.8 | 48.0 | 58.4 | 32.5 | 29.1 | 37.8 | 41.5 |
| pH | 8.8 | 8.3 | 8.4 | 7.4 | 7.5 | 7.2 | 7.2 | 7.2 | 7.5 |

Pine Swamp and Shepard Brook the highest concentrations and the greatest variations were observed. High algae counts in Pine Swamp did not seem to affect the sulfate concentrations materially. During the warmer weather surveys, when algae counts were high the average sulfate concentration was 13.5 ppm, as compared with 15.4 ppm during the colder weather (Table 1). In Shepard Brook a decrease from 12.2 ppm in the summer to 9.7 ppm in the winter was probably due to the correction of a summer sanitary violation on the watershed. The natural sulfate content tended to interfere and reduced the value of sulfate as an indicator of sanitary conditions.

*Phosphates*

The phosphate content of reservoirs is affected by the rocks, sands, fertilizers, wastes and the decomposition of organic matter in the bottom sediment. Although phosphates are generally present in very small amounts, they have been shown to have considerable significance in water biology (2), (9), (18).

With temperatures above 60°F. the phosphates at various locations in Mill River averaged between 0.14 and 0.09 ppm, indicating the watershed was a significant source. Decrease of this chemical in the surface waters of the reservoir to as low as 0.03 ppm at the Country Club may be attributed in part to removal by plant life. At the dam, where the sample was a cross-section of the upper ten feet, there was an increase to 0.09 ppm. A maximum phosphate concentration occurred in the fall at approximately the time of turnover. Further indications of the lower stratum's being an important source was substantiated by a later study at the Country Club, where the bottom phosphate averaged greater than 0.74 ppm with a maximum of 1.82 ppm.

Low winter phosphate values observed may be attributed to various factors. Probably most important is the effect of winter flows as high as 900 mgd upon the total storage volume of 390 mil gal. This would have a tendency to dilute and to flush out most of the phosphate. Unlike the nitrates, the phosphates were not increased by watershed run-off during peak flow periods. The content is also dependent upon the effect of tem-

perature on both the solubility of phosphates and the production by decomposition.

With regard to the other tributaries, the high phosphates of Shepard Brook may be attributed to the sanitary infraction, and those in Pine Swamp to agriculture and old subsurface drainage fields. Removal of phosphates in the summer was evident in Pine Swamp.

An increase in phosphates was generally followed by an increase in algae, a relation noted by other investigators (12). However, as shown in the discussion of *Cyanophyceae*, only small amounts were sufficient for large growths, while an excess exerted little or no effect.

### *Acidity, Alkalinity, and pH*

The utilization of carbon dioxide and bicarbonates by algae, accompanied by rising alkalinity and pH, has been frequently reported (4), (15).

When the water temperatures were above 60°F., the variation of pH from 7.0 to 9.3 for the reservoir stations may be attributed mainly to the effect of algae. Direct correlation between algae, pH and alkalinity with an inverse correlation between algae and acidity was observed at Waite St., where flushing action reduced the effectiveness of copper sulfate. On the other hand at the lower lake stations, Club and Dam, interference by copper sulfate was evident. Later in the summer, high flows resulting from two hurricanes nullified the effect of copper sulfate throughout the reservoir.

The slight variation of pH from 7.1 to 7.5 for the Mill River stations was accompanied by insignificant algae counts; however, the small pH variations from 6.9 to 7.3 for Pine Swamp, while high algae counts were being observed, may be attributed to the stabilizing effect of the buffering substances present.

The correlation of algae counts with pH, alkalinity and acidity was evident and generally agreed with the observations of other authors. However, exceptions such as the effect of buffering action in the swamp and the addition of copper sulfate in the lake tended to interfere. The utilization of carbon dioxide by algae was considered; however it was not pursued further because of the non-specific nature of the test employed.

### Shepard Brook

As indicated earlier, it was hoped this study would help in the evaluation of sanitary conditions of the watershed through a program of laboratory control. From samples collected during mid-summer, a sanitary infraction was disclosed in Shepard Brook, due to an inadequate sub-surface disposal system near the sampling station.

An examination of Table 4 will show how periodic examinations revealed the infraction. While most of the tests were helpful, the MPN appeared to be the most indicative.

Extremes in flows tended to obscure conditions. For minimum flows in the early part of August, the sub-surface strata tended to act as a biological filter until saturated. The effect of increasing flow is shown in the values for the remaining part of August, when extremely high runoff resulted in obscuring by dilution. Any interpretation must take into consideration flow variations.

The evaluation of sanitary conditions in this case was best made through the MPN, nitrite, nitrates and phosphates. Algae counts had very little relationship because of the greater influence of a pond directly above. The nitrites and phosphates were evident because of the short distance between the source and sampling points.

### *Correlation between Coliform Bacteria, Nitrates and Algae*

From stream-pollution studies it is well established that a high MPN of coliform bacteria is usually a result of recent pollution, whereas nitrates are generally indicative of past pollution. In the later stages of natural purification, when the stream has emptied into a lake or reservoir, decreasing MPN's and nitrates are usually accompanied by increasing numbers of algae. This sequence occurs when there is no subsequent pollutional interference downstream after the initial load. Thus, an increase of reservoir algae might be considered indicative of even more remote pollution. The extent of algae growth is dependent upon physical conditions and food available, especially the nitrates present.

The tributaries of the Whitney watershed were found to

contain relatively high MPN's, generally accompanied by high nitrates, indicating that the water was well along in the stages of self-purification. The following discussion of these correlations is based mainly on Table 1. During the summer the high nitrates in Mill River, which averaged 1.03 ppm, dropped to 0.4 ppm at the Waite St. sampling station in the lake, while the number of algae increased from a negligible count for Mill River to an average of 762 standard units at Waite St. This drop in nitrates and rise in algae count was accompanied by a marked drop in MPN from 7,300 to 427. Further substantiation of the sequence in the lower lake was not as evident. The lake stations showed a decrease in green and blue-green algae in the direction of the dam, while the nitrates increased. This effect may be attributed directly to copper sulfate. The MPN's continued as expected in the sequence and were reduced considerably by storage and possibly copper sulfate.

During the cooler period the algae counts were negligible, while the nitrates were substantially unchanged, due to lower temperatures and high flows. The marked drop in MPN was still evident; however, it moved down the lake and decreased from 1,230 at Waite St. to 424 at the Country Club.

In the stream the MPN's were the best indicators of sanitary conditions on the watershed; however, in the lake their value as an indicator was dependent on storage. The value of nitrates as an indicator of sanitary conditions was influenced by the assimilation by plants, especially during periods of active algae growth. The effect of the addition of copper sulfate upon the growth of the algae must also be considered. During the colder, dormant periods, the nitrates are freed of significant algae interference and are more indicative of sanitary conditions on the watershed.

## Summary

Prior to the creation of this program for laboratory investigation of watershed conditions, careful consideration was given to the location of sampling points. Samples from the intake were valuable, but inadequate. Strategically located points on the lake and tributaries provided information for the early control of an algae bloom and elimination of a sanitary infraction.

Most of the factors selected for this study had a fairly direct relation to wastes. Algae presented the possibility of useful correlations.

Chlorides and sulfates were of value when a sanitary infraction happened to be close to the sampling point and dilution was insignificant. High normal chlorides, due to proximity of Long Island Sound and the natural sulfate content of the area, tended to interfere and reduce the value of these chemicals as indicators.

The natural phosphates of potable surface waters may be sufficiently high to obscure a possible sanitary violation which might occur on a watershed such as Lake Whitney. Also due to the many interfering factors, the phosphates while giving some indication of sanitary conditions were not of the same value as in a stream more directly affected. The fact that only small amounts are required for algae nutrition also limited the usefulness of the phosphate determination.

From this study coliform bacteria, nitrates and algae were helpful in watershed inspection.

The coliform bacteria were very useful due to the sensitivity of the test. However, consideration had to be given to the effect of seasonal conditions and duration of storage, and the significance of coliform bacteria not of sewage origin. Nitrates and algae, because of their direct relationship, had to be considered together. The absence of nitrates was indicative of good conditions only when the algae were also absent. The effect of copper sulfate, temperatures and flow upon algae also had to be considered.

For the Lake Whitney watershed the following laboratory examinations appeared to be best for interpreting sanitary conditions: for streams, coliform bacteria with nitrates; for swampy areas, coliform bacteria with algae in summer and nitrates in winter; for the reservoir, algae with nitrates in summer and coliform bacteria with nitrates in winter. Deviations from such established quantitative relationships will indicate changes in sanitary conditions.

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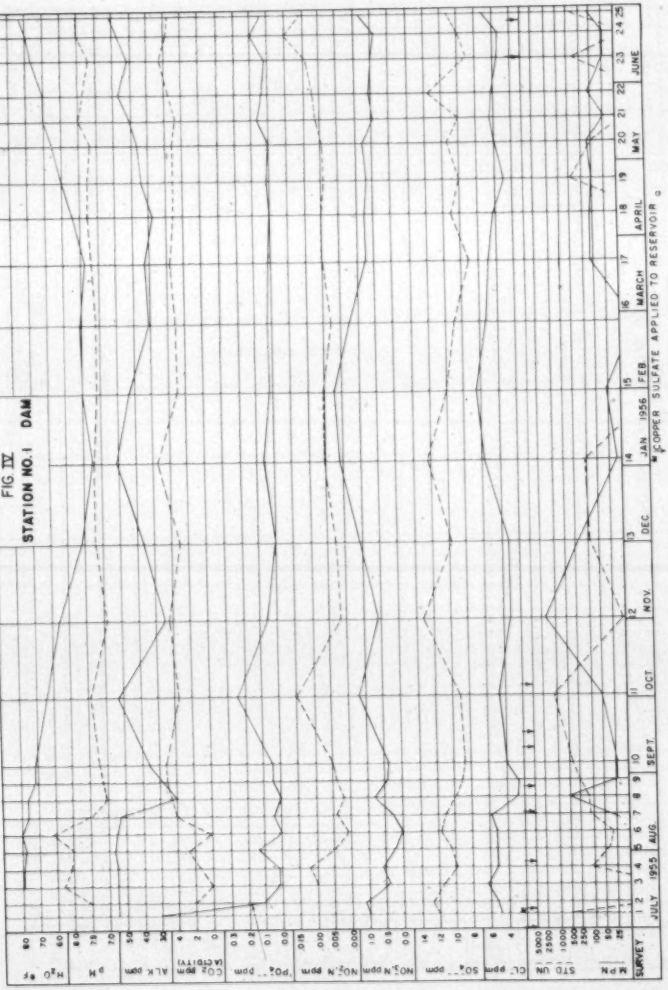
FIG. IV
STATION NO. 1 DAM
H2O °F
pH
ALK. ppm
CO2 ppm (ACTDITY)
PO4 ppm
NO2 N ppm
NO3 N ppm
SO4 ppm
CL ppm
STD. UN.
M.P.N.
SURVEY
JULY 1955
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN. 1956
FEB.
MARCH
APRIL
MAY
JUNE
COPPER SULFATE APPLIED TO RESERVOIR

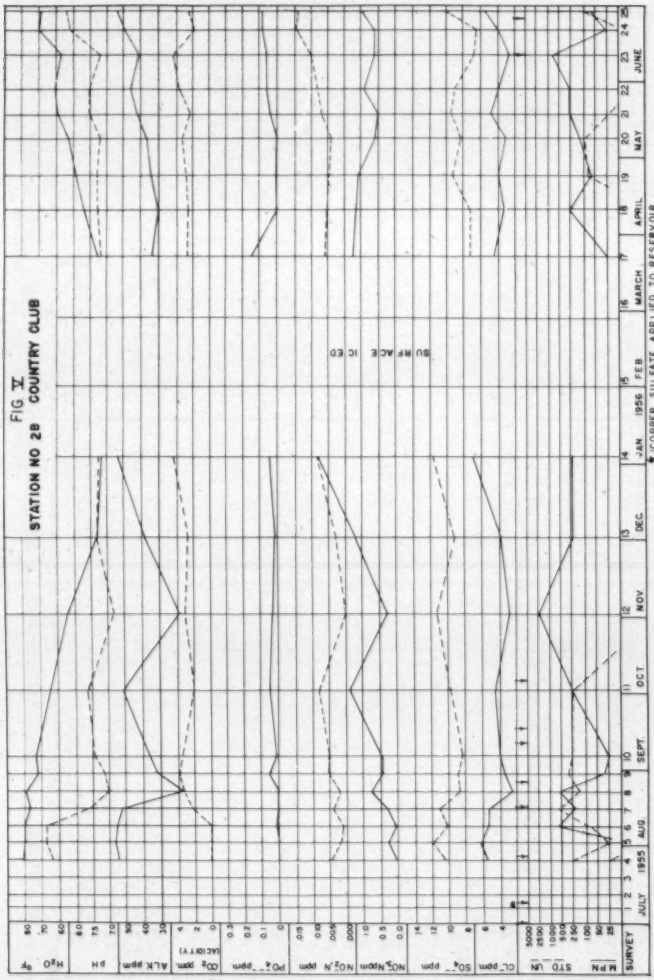
FIG X
STATION NO 28 COUNTRY CLUB
SURFACE ICED
* COPPER SULFATE APPLIED TO RESERVOIR
JULY 1955 AUG SEPT OCT NOV DEC JAN 1956 FEB MARCH APRIL MAY JUNE
SURVEY
MPN
STD UN
CL ppm
SO4 ppm
NO3 N ppm
NO2 N ppm
PO4 ppm
CO2 ppm (ACIDITY)
ALK ppm
pH
H2O °F

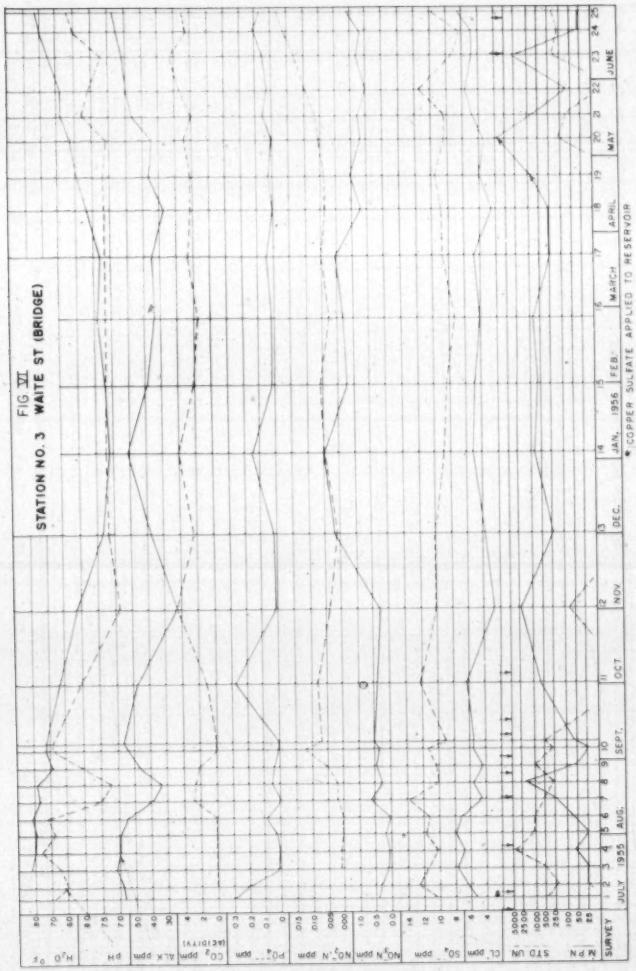
STATION NO. 3 WAITE ST (BRIDGE)
COPPER SULFATE APPLIED TO RESERVOIR
SURVEY
JULY 1955
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN. 1956
FEB.
MARCH
APRIL
MAY
JUNE
M.P.N.
STD. UN.
CL ppm
SO4 ppm
NO3-N ppm
NO2-N ppm
PO4 ppm
CO2 ppm (ACIDITY)
ALK. ppm
pH
H2O °F

FIG VI

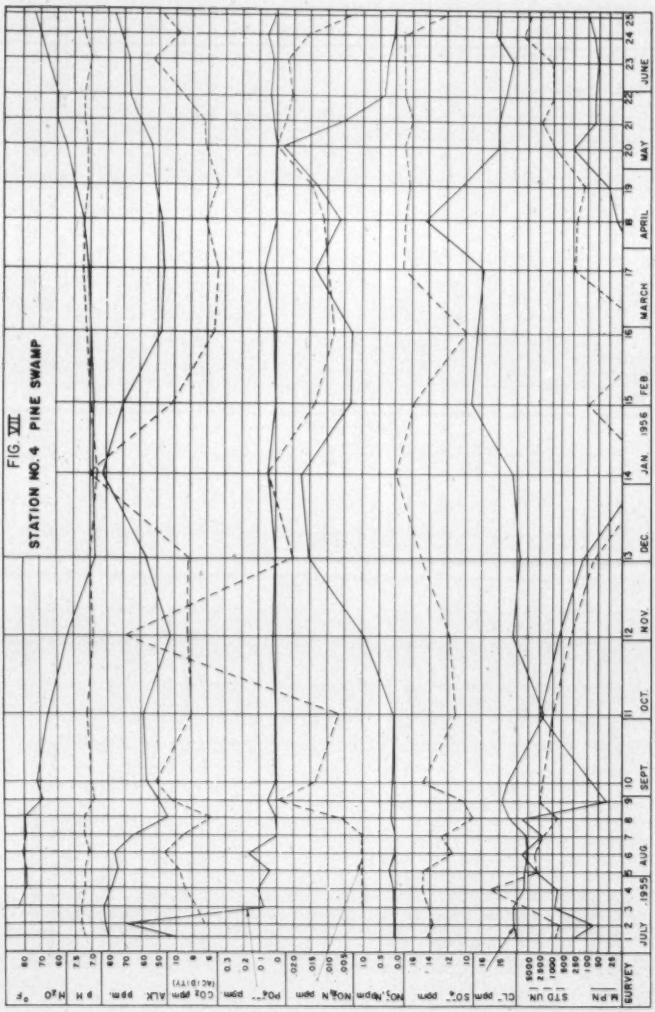


FIG. VII
STATION NO. 4 PINE SWAMP

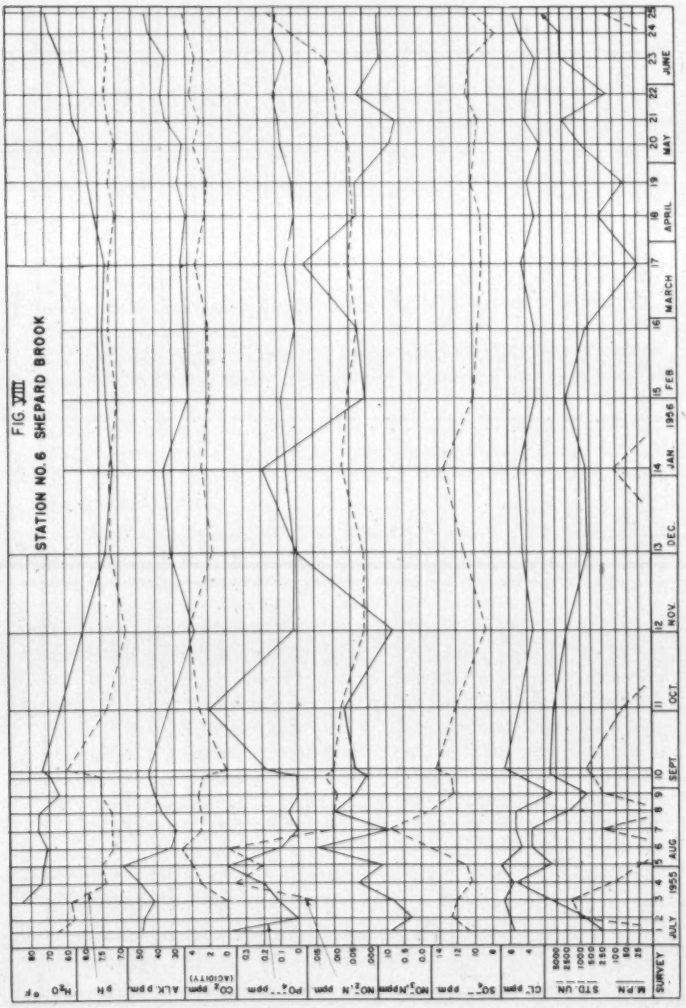


FIG. VIII
STATION NO. 6 SHEPARD BROOK

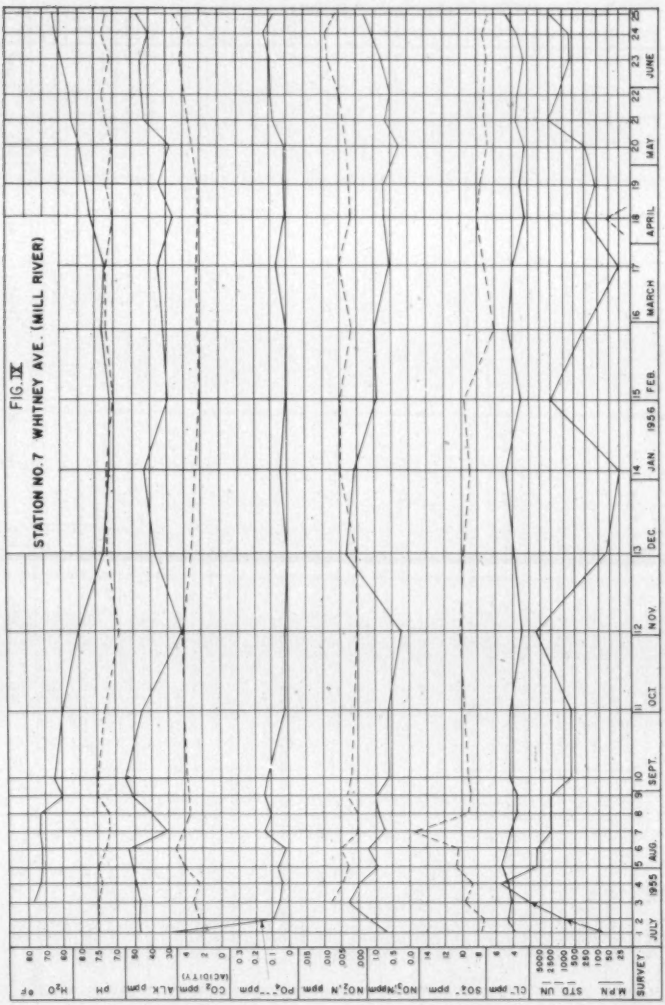


FIG. IX
STATION NO. 7 WHITNEY AVE. (MILL RIVER)

# HOW SUPERVISORY CONTROL CAN HELP NEW ENGLAND WATER SYSTEMS

BY B. L. SOSCIA*

[*Read September 15, 1958.*]

The water-works industry, like other industries in this country, must keep up with modern technological advances if it is to keep pace with a growing America. As America expands, our needs expand, and these include the need for water. Formerly, a water system often consisted of a river intake, treatment plant and pumping station, all at the same location. Now the situation is quite different. Many intakes and reservoirs are often linked to one treatment plant, and elevated storage tanks and booster pumping stations are scattered throughout large cities. To extend the problem further, a central treatment plant and pump station may supply water to many outlying towns, many miles from the central station.

As the water systems grew and spread, so did the operational problems. Where all of the controls were in one place, now they are widely dispersed. Telemetering information was the first aid to the water-works profession, then elementary remote control, and now the ultimate in automatic operation, a central supervisory control system.

A supervisory control system provides operating personnel with (1) adequate supervision of remote equipment, (2) operating information about the status of all equipment, and (3) telemetry over a common transmission link or channel. Combining the American Standard definitions for supervisory control, indication and telemetry, a supervisory system may be defined as "equipment for the selective control, automatic indication and continuous telemetering to or from remotely located units by electrical means over a relatively small number of transmission channels."

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## Water-Works Application

When applied to water works, a supervisory system furnishes (1) central control and operating conditions of remote pumps, regulating valves, gates, chemical feeders, fans and lawn sprinklers; (2) central operating conditions of local automatically controlled pumps, valves or standby generators; (3) central alarm indications, such as bearing temperatures, room temperatures, room flooding and doors open or closed, and (4) central continuous telemetering of levels, flows, pressures, voltages and currents.

The prime benefit gained from the application of supervisory control to a water-works system is reduced operating expenses by minimizing or reducing mobile equipment, mileage and upkeep. Depending upon the system requirements, other gains are as follows:

(a) High dependability—by keeping constant watch over remote areas 24 hours a day and eliminating human error.

(b) Skilled personnel released for other duties by centralizing operational and control information and allowing personnel to perform additional services.

(c) Low-cost system expansion—through initial system planning, enabling additions for future growth, as required, without changing over-all equipment.

(d) Increased system efficiency and productivity—by instantaneous control and indication of system operation. Demands can be satisfied as needed—reducing time lag involved in uncoordinated systems.

(e) System failures pinpointed immediately by having constant system monitoring and allowing quick dispatching of repair or maintenance personnel.

(f) Improved customer relations through improved service, by responding quickly to system changes, as sensed and indicated before or during an emergency.

Growing operating costs and our present economy command that centralized control, automatic operation and unattended substations become a necessity.

## Choice of Transmission Link

Supervisory control is especially adaptable for control and telemetering between stations usually separated by distances in excess of one-half mile. It is common to find supervisory-control dispatching equipment in water superintendents' offices, maintenance quarters, city halls, fire stations, booster stations and water-treatment plants, and supervisory-control receiving equipment located in well fields, lake or river low-lift stations, booster-pump stations, valve vaults or water-treatment plants.

If the dispatching center is located reasonably near the remote receiving station where equipment to be controlled is situated, the problem of controlling or monitoring is made relatively simple by installing multi-conductor cable between dispatching and receiving stations, at reasonable costs. Spare cable pairs must be contemplated in advance, for future additions to the system and replacement for open or shorted pairs.

If the dispatching center is located at a distance from the receiving station, the problem of controlling and monitoring becomes more involved, because a multi-conductor cable is usually costly to install and maintain. In many situations, rights-of-way for private multi-conductor cable cannot be obtained and, consequently, cost cannot be evaluated. In such cases, an evaluation of the transmission link is made, considering (1) carrier, (2) micro-wave, (3) radio and (4) leased telephone lines. The use of a leased telephone-line link is usually selected, because it is maintained at no additional cost, appears to be more reliable for water-works transmission distances, which average 15 to 20 miles, and in the over-all analysis, costs less over a period of years.

Most supervisory control systems can be adapted to any of the four types of transmission links. However, since applications in New England, at the present time, can be efficiently handled by private or leased pairs of telephone lines, the balance of this paper will deal only with supervisory control and telemetry over this type of link or channel.

## Various Channels

Following is a list of the various types of channels used to

interconnect dispatching and remote supervisory-control equipment:

*A. Metallic Pair of Wires.* A pair of wires which provides a path for direct-current flow between stations. Usually, metallic pairs are required for systems employing a DC pulse coding type transmission. Line resistance, inductance and shunting capacitance limit the maximum keying rate and maximum transmission distance permissible.

*B. Voice Channel.* A voice channel is often a metallic pair, although DC continuity is not necessary for passing frequencies in the audio spectrum between 300 and 2,800 cps. Inter-exchange lines are generally metallic pairs. Intra-exchange lines usually are loaded with repeaters, or carrier equipment, and cannot pass direct current. The advantages of a voice channel are as follows:

1. Simultaneous functions can be performed in the same or opposite directions.

2. Where local telephone companies permit it, simultaneous voice communication and supervisory control are possible over one channel.

3. Multi-station arrangement is possible, using one channel interconnecting all stations.

4. Future expansions can be made simply by extending the signal channel.

Because of the increase in use of telephone-line transmission, new transmission facilities, such as cables and central-office equipment, are primarily designed to accommodate and multiplex voice communications. This fact should be borne in mind when contemplating design of present or future supervisory control systems.

*C. Telegraph Channels.* A telegraph or teletype channel is characterized by the fact that it can only transmit pulses at a high keying rate up to about 100 per second. Three types of telegraph channels are available:

1. One-direction channel (transmission in one direction only).

2. Half duplex (single-direction transmission: transmitter to receiver or receiver to transmitter).

3. Full duplex (transmission in both directions simultaneously).

In general, a telegraph channel (1) cannot transmit audio frequencies or direct current between stations; (2) is less expensive than a voice channel, and (3) is more expensive than a metallic pair.

*D. Telephone Line Carrier.* Telephone lines are rarely leased to private users for purposes of multiplexing with carrier equipment, resulting in several voice channels which could either be used for voice communications or be subdivided for tone telemetering or supervisory control. Telephone companies usually employ carrier frequency equipment to provide several channels over a metallic pair between exchanges.

## Transmission-Link Layouts for Multi-Station Systems

In planning a supervisory control system which involves a multi-station layout, the arrangement of telephone lines is very important. The channel is usually considered the weakest link in a supervisory control system. In view of the cost of the terminal equipment, the goal is to attain a line layout with the best possible evaluation of these factors:

(a) Rental, new installation and maintenance costs.

(b) Effect upon reliability, accuracy and serviceability by changes in line characteristics, line failures and power failure at remote stations and telephone exchanges.

(c) Versatility and flexibility for future, as well as present, functional requirements.

Telephone-company transmission engineers are available and usually in the best position to assist in planning a layout, since they have at their disposal exchange-office locations, line make-up, attenuation figures and line-rental costs. On the other hand, if this information is made available, equipment manufacturers welcome the opportunity to plan an efficient layout.

Figure 1 illustrates four remote stations, each planned in conjunction with a master supervisory-control unit at the dis-

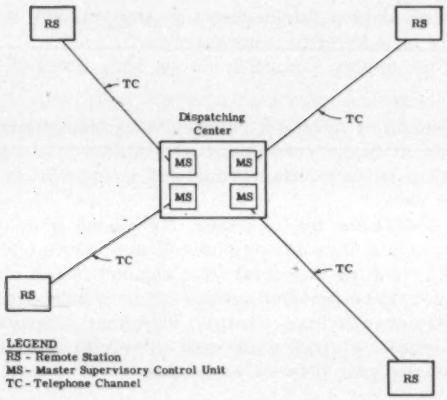


FIG. 1.—"SPOKE-WHEEL" LAYOUT OF FOUR STATION-TO-STATION CHANNELS

patching center for station-to-station operation. A common master supervisory-control unit can be furnished at the dispatching center. Where remote stations are scattered about a central dispatching center, in "spoke-wheel" fashion, individual station-to-station channels afford maximum system reliability and expansion. In addition, each channel can be easily monitored to sound an alarm at the dispatching center, should the channel fail due to a break, short or change in line attenuation.

Figure 2 shows the multi-station telephone-line layout planned for the Metropolitan District Commission, Arlington, Mass., by Coffin and Richardson, Inc., consulting engineers, with all terminal functions outlined. Complete system equipment, both supervisory control and telemetering instrumentation, is being furnished by B-I-F Industries, Inc., of Providence, R. I.

## TYPICAL INSTALLATIONS

The series of figures which follows shows how supervisory control equipment is applied in the production, treatment and distribution of water from two functions at a remote well to multiple functions at a treatment or booster-pump station.

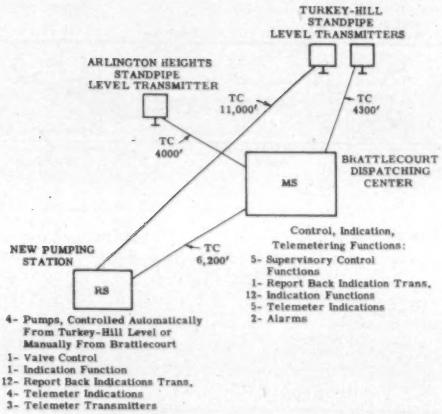


FIG. 2.—MULTI-STATION SUPERVISORY CONTROL SYSTEM FOR METROPOLITAN DISTRICT COMMISSION, ARLINGTON, MASS.

*A. Two-Function Control-Indicator Units.* An elementary supervisory-control arrangement, shown in Figure 3, can be used for controlling a remote pump or valve and receiving a positive "report-back" indication simultaneously over a common metallic pair or link. The function mixer and separator use polarized DC and static devices for efficiently and economically channeling the control signal to the motor, and the report-back signal to the indicating lamps. This equipment is recommended by the manufacturer for simultaneously performing two functions in the same or opposite directions, and does not employ timers for time-sharing purposes.

*B. Two-Function Position-Indicator Units.* A similar control arrangement, employing static devices, is used for remote nudging, jogging or regulating the position of a valve, gate or variable-speed drive. This position-indicator controller is shown in Figure 4. The control switch is usually spring-loaded to return to the center "STOP" position. A low-current (1-milliampere), DC, potentiometric position indicator is incorporated within this

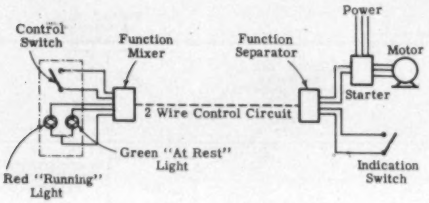


FIG. 3.—CONTROL AND INDICATION (REPORT-BACK) OVER A COMMON CONTROL CIRCUIT.

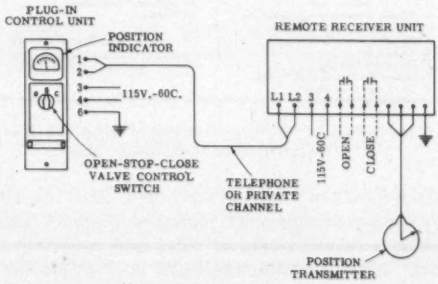


FIG. 4.—POSITION INDICATOR-CONTROLLER FOR REMOTE NUDGING OR POSITIONING.

unit, to show continuously the actual valve position, as the operator "nudges" it to a new position.

*C. Multi-Station Systems.* For multi-station systems, comprising telemetering transmission and several control and alarm monitoring combinations, the use of audio tone-frequency units over a voice-channel link is considered most economical. Figure 5 shows an arrangement utilizing plug-in type, rack-mounted, transistorized tone transmitters and receivers. Each function requires a tone channel, consisting of a tone transmitter, TT, and a tone receiver, TR. About 26 tone channels may be applied to a characteristic voice channel.

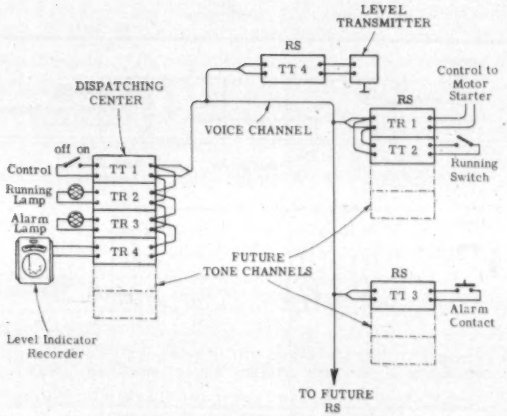


FIG. 5.—MULTI-STATION SYSTEM USING AUDIO TONE UNITS OVER A COMMON VOICE TELEPHONE CHANNEL.

Figure 6 is an external-wiring and functional diagram, illustrating the transmission of an alarm function via audio tone. A contact closure across the *"Key"* and *"Ground"* terminals of a transmitter causes oscillations of its characteristic frequency to be emitted on the signal line. This frequency is accepted at any point along the signal line by an associated receiver, whose filter passes only this signal to its amplifier section, to key a relay. Normally open or closed contacts on this relay may directly energize metering, control, alarm or indicating devices.

*D. Multi-Function Scanning Systems.* When multiple functions are to be transmitted between a dispatching center and a remote station, complete terminal equipment is furnished in appropriate free-standing cubicles, all factory-assembled, wired and tested.

Basically, all multi-function supervisory control systems employ one of the folowing modes of transmission, or a combination of them:

(a) Pulse code, such as pulse count, pulse-space or binary code.

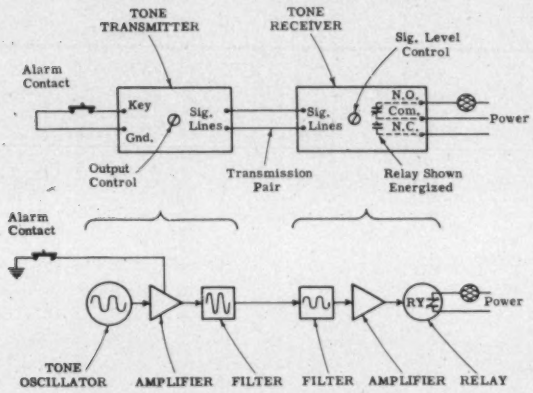


FIG. 6.—EXTERNAL WIRING AND FUNCTIONAL DIAGRAM OF ASSOCIATED TONE TRANSMITTER AND RECEIVER.

(b) Tone code.
(c) Scanning-switch sequencing.

The application of an intermittent scanning system, utilizing audio tone transmission, is illustrated in Figure 7. This system features synchronized motor-driven scanning switches, which automatically scan only when a control function is initiated from the dispatching center, or disagreement is sensed at a remote station. Each scanning switch is rotated by a constant-speed motor at a speed of 1 rpm. During one revolution of the switches, as many as fourteen control functions may be initiated, and all report-back indications are monitored. The basic system employs four tone channels to perform 28 functions, control or advisory. Twenty-two additional tone channels are available for continuous telemetering, jogging operations or instantaneous alarms.

## CONCLUSIONS

Various types of equipment are available to perform the operations outlined in this discussion. Each has been thoroughly field-tested on actual installations throughout the country over a

period of years. The economies and system performance accomplished with supervisory control have been proven. It is extremely important, in over-all planning, to investigate the use of supervisory control and to apply it to the best advantage in each water-supply system.

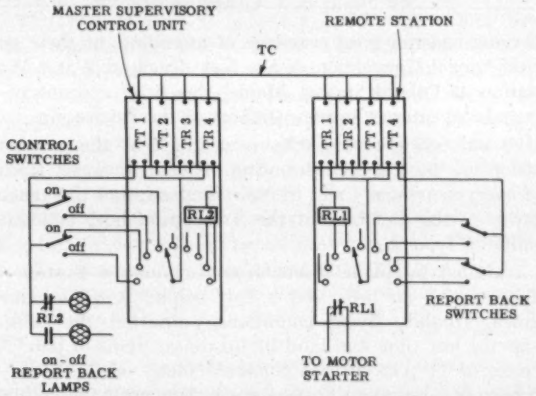


FIG. 7.—ELEMENTARY DIAGRAM OF INTERMITTENT SCANNING SYSTEM.

# THE POLAND SPRING CONVENTION OF THE NEW ENGLAND WATER WORKS ASSOCIATION*

BY CHARLES A. RISBRIDGER†

Having had the great privilege of attending, as their guest, the 76th Annual Convention of the New England Water Works Association at Poland Spring, Maine, this brief account of my visit may be of interest to the members of the Institution.

It is but fitting to begin by recording that the paramount impression left by a most interesting visit is the warm friendliness of everyone whom I met in New England, and the generous hospitality of the members of the Association both collectively and individually.

I travelled by plane direct from London to Boston, and although starting an hour and a half behind schedule, due to mechanical trouble, flying conditions permitted the pilot to make up the lost time and land in Boston at about 6 p.m. New York time or 11 p.m. British Summer Time, on Tuesday, 9th September. My host and hostess from then until the following Sunday, the eve of the Convention, were Mr. and Mrs. Sherman Chase, well-known visitors upon three or four occasions to our Summer Meetings, and most successful ambassadors of goodwill from the New England Water Works Association. During my stay with him Mr. Chase very kindly drove me to the main source of the water supplied by the Metropolitan District Commission, the Quabbin Reservoir, in which are impounded the waters from 186 sq. miles of the upland gathering grounds of the Swift River. The Commission supplies water to thirty municipalities, including the City of Boston, the estimated population of the areas supplied being 1,808,000 in 1956 when the daily consumption was 168 million Imperial gallons, or 93 Imperial gallons per head per day.

Within the scope of this account it is impossible to do more

*Reprinted from *Journal of the Institution of Water Engineers*, Vol. 12, No. 7, p. 473, Nov., 1958.

†President of the Institution of Water Engineers.

than give a very brief description of the supply works, of which the Quabbin Reservoir is the most outstanding in magnitude. It is situated about 65 miles west of Boston and is created by two earth dams, the one, the Winsor Dam, 170 ft. high above river bed and 2,640 ft. long, and the other, the Quabbin, 135 ft. high above river bed and 2,140 ft. long.

The Winsor Dam is named after the late Chief Engineer of the Commission. The reservoir is in the form of two interconnected parallel legs, one about 11 miles and the other about 15 miles long, the total water surface at 530 ft. above sea level being about 38½ sq. miles with a shore line of 118 miles. The maximum depth is 150 ft., and some idea of the ideal nature of the site may be gained from the fact that 8 miles above the dam the average depth is about 90 ft. The capacity is 343,000 m.g.

Water from Quabbin Reservoir flows through an aqueduct in the form of horse-shoe shaped tunnel in rock, 24½ miles long and of a cross-section equivalent to a circle 12 ft. 9 in. in diameter, into the Wachusett Reservoir, which is formed by a masonry dam 115 ft. high above river bed and has a capacity of 54,100 m.g. with T.W.L. 395.

From that reservoir the water flows through a tunnel-conduit-open-channel aqueduct of 266 m.g.d. capacity to reservoirs within a few miles of Boston. Where the Quabbin Aqueduct crosses under the Ware River, water from the river in excess of an agreed minimum may be diverted down a vertical shaft into the Aqueduct by a most ingenious system automatically controlled by the vacuum created by the passage of the compensation water through a Venturi meter from upstream to downstream of the diversion weir. The effect of the facilities for diverting the Ware River is to add 98 sq. miles of that river to the gathering grounds of the Quabbin Reservoir for the water may be made to flow by gravitation to, and stored in, Quabbin Reservoir or to Wachusett Reservoir, or to both simultaneously, at a combined rate of something over 700 m.g.d. The scheme thus serves the dual purpose of conservation and flood control in the Ware valley.

I had the pleasure of meeting the engineer who designed the Ware intake—Karl Kennison,* now retired from practice—who

*Latest recipient of the Diploma awarded under the reciprocal agreement between the Institution and the N.E.W.W.A. (*Journal of the Institution of Water Engineers*, 1956, vol. 10, p. 558).

very patiently explained his design by means of sketches on the back of a luncheon menu. My very real interest in his ingenious scheme, coupled with his enthusiasm in explaining it, quickly established us as such intimate friends that I was able to share his bag of golf clubs for a round of only four holes, during which he played so much better than he expected after a lapse of some years, that I fear I may have resuscitated a vice of which he had believed himself cured.

In describing some of the features of the works of the Metropolitan District Commission, my only purpose was to give some idea of their magnitude and the only other mention I would make of them is that the water is not treated in any way except by chloramination and occasionally with copper sulphate to control algal growths. Consequently sanitary rules and regulations on the watershed are strictly enforced. I found some considerable concern—understandable in the circumstances—among members of the Association at a growing demand from the public for use of water supply reservoirs for recreational purposes.

The Convention was held at Poland Spring House, Poland Spring, Maine, a highland resort. The hotel, of gigantic proportions, is constructed entirely of timber, as are the majority of the residential buildings in New England.

The proceedings opened on the Monday, 15th September, at 10 a.m., with the business meeting at which the Chairman of each of several subcommittees presented his report of the proceedings thereof.

In the afternoon three papers were presented. Contrary to the practice at our own meetings, the papers are not circulated beforehand, nor apparently is anyone briefed to open a discussion. Instead, the author reads his paper in its entirety and presents his figures and graphs, if any, by means of slides. It is, of course, quite impossible for an audience to analyse figures presented either in tabular or graph form in those circumstances, and not at all easy to follow the author's argument if the subject-matter is at all abstruse. As a consequence, at question time at the end of the author's reading, the number of questions put was very small and the discussion, if any, very limited.

In the evening I was the guest at a Past Presidents' Dinner. As an aid to the digestion of an interesting and satisfying meal, Mr. Chase afterwards showed some coloured slides of his recent European tour including some from the Summer Meeting of the Institution.

This was followed by a function entitled "Harvest Jamboree," and described as "our annual swing-ding. Come along and swing your partner." It was in fact a most enjoyable and decorous session of square dancing in the barn at which the men were presented with large straw hats, the ladies with poke bonnets, and everyone who needed them with cider and doughnuts at appropriate intervals.

The morning of the second day was devoted to three more technical papers, and the afternoon to a men's golf tournament. In between there should have been a "Picnic in the Pines," but as it rained the picnic—a barbecue—was held in the hotel. In passing along a trestle table heavily laden with food and lined with chefs, one's plate was loaded with every kind of cold meat, vegetables, salads and pickles, and just when it appeared possible to hold no more, a whole lobster was added to it. It is understandable why the afternoon was given over to a golf tournament. The evening was taken up by a first-class entertainment entitled "Stelliferous Revue."

On the Wednesday morning three more papers were read, including my own entitled "Current Affairs in the Water Supply Service in Great Britain." The matter which provoked most discussion was the consumption per capita in Great Britain, and the reasons why it is so much smaller than that in the United States.

In the afternoon five more papers were read at a Superintendents' Session. It appears that, as a rule, water undertakings are operated by superintendents, who are not generally professional engineers, the construction and development works being designed and supervised by consulting engineers. From my discussions on this subject there appeared to be a trend towards a departure from the practice, but it would be likely to be slow in progress because of a lack of qualified engineers available for, or willing to take, such posts.

In the evening of the third and last day, the Banquet took place, at the conclusion of which medals for papers, etc., were awarded, and certificates of Honorary Membership were presented to three members and to one guest, the President of the Institution of Water Engineers. I put it that way because the gesture is obviously in honour of the Institution and not of one member thereof, who for the time being was privileged to be its President and to take part in the Convention.

After the presentations I expressed—inter alia—the cordial greetings of the Members of the Institution and my appreciation of the compliment which they had paid to the Institution by conferring upon me the vicarious distinction of Honorary Membership.

In making the presentation, the President, Mr. George G. Bogren, referred to the happy relations between the Institution and the Association and asked me to convey to our members the cordial greeting of the Association.

Then followed the Presidential Address of the outgoing President and the installation of the new President, Clarence L. Ahlgren.

So ended an interesting meeting, a happy mixture of work and pleasure, much like our own Summer Meeting in general, except for the absence of those visits to works which characterize our meetings, and perhaps rather more emphasis on the social recreational events. The absence of visits to works is readily explained by the spaciousness of the country, towns and waterworks being much more widely spaced than in our highly developed country.

As I began this account, so would I like to end it, by referring to the kindly nature and courtesy of the New Englanders, illustrated by a casual meeting in Boston Public Park. There are over 800,000 inhabitants, and one of them had to stop me to enquire his way to a certain building. Upon telling him that I had only just arrived there from England he replied, "Well, isn't that something! Welcome, Sir, and I hope you'll enjoy our City." This took place within the shadow of a monument commemorating the eviction of the English about 200 years ago. Therein

lies material for a philosophic dissertation, but I will resist temptation.

The journey home was somewhat frustrating. Upon arrival at Boston Airport a little before 10 p.m. (N.Y.T.) to catch a plane at 11.40 p.m. I was informed that the flight was cancelled. Having an appointment with the Northern Ireland Section at their meeting the following evening, I asked for alternative accommodation, and was flown to La Guardia Airport, New York. From there a taxi took me to Idlewild Airport to catch a plane half-an-hour after midnight. Unfortunately the plane had mechanical trouble and did not take off until 2 a.m., arriving at Prestwich with time to reach Renfrew by taxi in time to catch the plane to Belfast. However, it was Ayr Races day and it took half-an-hour for a taxi to appear. Every traffic light was at red and to make quite sure that I should miss the connexion a learner driver had to come to grief straddling the carriage-way at a traffic island. In spite of the fact that the plane had been held back for a quarter of an hour, it took off as I reached the airport. " 'Tis an ill wind," etc., for I was able to return to Glasgow for a good night's sleep in partial compensation for the lack of it the previous night, and therefore enjoyed the better the day's events with our good friends in Northern Ireland.

## MEMOIR OF ARTHUR D. WESTON

The late Arthur D. Weston joined the New England Water Works Association on January 12, 1922, and was made an Honorary Member on September 19, 1944, after having served as President for 1928-1929. He served with wisdom on many committees. In 1951 Mr. Weston received the Dexter Brackett Memorial Award for his paper, entitled "Sanitary Protection of Watersheds—Are We Overdoing or Underdoing It?" The New England Water Works Association lost a friend and counsellor when he passed away on December 20, 1958.

THE LATE ARTHUR D. WESTON

Mr. Weston was born in Boston, July 18, 1884, and received his formal education in the Boston public schools and Dartmouth College. His search for enlightenment in engineering and the humanities was a lifelong pursuit.

His principal activity in the engineering field was with the Massachusetts Department of Public Health. He joined the Department in 1905 and, except for the period 1908-1912, continued in the service of the Commonwealth until World War I. He served as Captain in the American Expeditionary Forces in France with the 26th Engineers Water Supply Regiment. After the Armistice, Mr. Weston returned to the Department as Principal Assistant Engineer, was promoted to Associate Engineer and, in 1930, succeeded Mr. X. Henry Goodnough as Chief Sanitary Engineer and Director of the Division of Sanitary Engineering. In 1948 he was designated Deputy Commissioner of Public Health. Mr. Weston retired from State service on December 31, 1949, and thereafter worked as a consultant in the field of sanitary engineering.

In the course of his long association with the Division, Mr. Weston brilliantly led programs to protect and promote the public health in the field of environmental sanitation. His professional excellence and outstanding personal qualities of integrity and warmth were well known by his numerous associates in public life and professional activity. The man reflected credit on the Division, raised the stature of the profession and deeply influenced many younger engineers.

He was very active in engineering societies and played leading roles in sanitary engineering matters. He was Past President of the Boston Society of Civil Engineers, of the Northeastern Section of the American Society of Civil Engineers, of the Engineering Societies of New England, of the New England Water Works Association, of the National Conference of State Sanitary Engineers, and of the New England Sewage Works Association. He also served as chairman of the Sanitary Engineering Division of the American Society of Civil Engineers.

Mr. Weston leaves his wife, Edna Vose Weston; a son, Julien Vose Weston; a daughter, Mrs. Arthur L. Besse, and three grandchildren.

FRANCIS H. KINGSBURY

# PROCEEDINGS

## November 1958 Meeting

### Hotel Statler, Boston, Mass.

### Thursday, November 20, 1958

President Clarence L. Ahlgren in the Chair.

Secretary Knox announced the election by the Executive Committee of the following new members:

Robert E. Barry, Superintendent, Water Department, Quincy, Mass.; John J. Russell, Vice-President, Consumers Water Co., Portland, Me.; James S. Mulroy, Superintendent, West Boylston Water District, West Boylston, Mass.

*Associate:*

Eastern Survey and Engineering Co., Inc., Boston, Mass.

A paper on "Water Plant Automation" was read by Raymond H. Condell, Systems Engineer, Fischer & Porter Co., Hatboro, Pa.

A paper on "The Break-Point Process for Free Residual Chlorination" was read by A. E. Griffin, Technical Consultant, Division of Technical Services, Wallace & Tiernan, Inc., Belleville, N. J.

## December 1958 Meeting

### Hotel Statler, Boston, Mass.

### Thursday, December 18, 1958

President Clarence L. Ahlgren in the Chair.

Secretary Knox announced the election of the following new members:

Edward E. Begin, Chief Engineer, Quittacas Pumping Station, New Bedford Water Works, New Bedford, Mass.; William A. Magoon, Superintendent and Treasurer, Water Works, Salem, N. H.; John J. Mahoney, Resident Engineer, Whitman & Howard, Inc., Boston, Mass.

*Associate:*

Cutler-Hammer, Inc., 415 Western Ave., Brighton, Mass.

*Corporate:*

Board of Water Commissioners, West Springfield, Mass.

A paper on "Recent Improvements to the City of Peabody, Mass., Water System" was read by Clifford S. Mansfield, Senior Engineer, Fay, Spofford & Thorndike, Inc., Boston, Mass.

A paper on "Weather Cycles and Rainfall" was read by Robert L. Hendrick, Weather Research Center, Travelers Insurance Co., Hartford, Conn.

A film—"Water for Everyone"—was shown through the courtesy of Robert Klemme, Armco Drainage and Metal Products, Inc., Boston, Mass.

## JANUARY 1959 MEETING

### HOTEL STATLER, BOSTON, MASS.

### THURSDAY, JANUARY 15, 1959

President Clarence L. Ahlgren in the Chair.

Secretary Knox announced the election of the following to membership in the Association:

Tracy I. Flagg, Health Agent, Danvers, Mass.; Lewis W. Soule, Water Commissioner, Onset, Mass.; Neal Z. Mitchell, City Engineer, Salem, Mass.

*Associate:*

Mercer Marine, Boston, Mass.

PRESIDENT AHLGREN. I regret to announce that since our last meeting here in Boston two of our distinguished members have passed away. I should like to have you stand up as I read their names:

Arthur D. Weston, a Past President of the Association; Theodore W. Grindle, Superintendent, Bar Harbor Water Co.

I am going to call on Edwin Cobb to make a committee announcement.

EDWIN B. COBB. Perhaps some of you gentlemen know that I am one of the representatives of the Water Works on the ASA Committee 21, which has to do with specifications for cast-iron pipe and fittings. This committee is being reactivated, to consider the specifications and to recommend any changes which

seem desirable. If any of the members have any ideas that they would like to transmit to us, we should appreciate receiving them, so that we can consider them and see if they are matters which should be considered by the main committee. I thank you.

PRESIDENT AHLGREN. I should now like to call on Bill Duffy, chairman of the Scholarship Fund Committee, for an announcement relative to the work of that committee.

WILLIAM B. DUFFY. To those of you who have copies of the program I should like to call attention to a couple of lines on that program which say, "A contribution to the Scholarship Fund will further a most worthy project of the N.E.W.W.A." I should also like to tell you that at the end of the year we have received several contributions to the Fund, and one of them that is worthy of comment, I think, is of $1,000. Karl Kennison, a former President, gave us a thousand dollars, which helps the Fund a great deal. We have $11,500 in the Fund now. Since, as you know, we can use only the interest from the fund, to make scholarship grants, I hope that those of you who can will keep in mind that we shall be happy to receive contributions at any time.

A talk on "New England Geology" was given by Dr. Ruth Terzaghi, Professor of Geology, Harvard University, Cambridge, Mass.

A paper on "Simplification of the Analysis of Complex Water-Works Distribution Networks" was read by Edwin B. Cobb, Partner, Metcalf & Eddy, Boston, Mass.

A talk on "Radiological Health Activities of the Division of Sanitary Engineering in Massachusetts" was given by John C. Collins, Sanitary Biologist, Massachusetts Department of Public Health, Boston, Mass.

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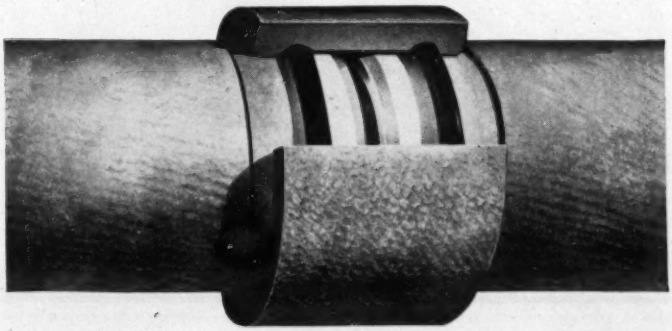

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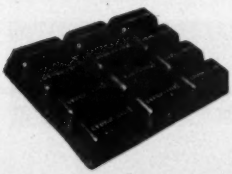

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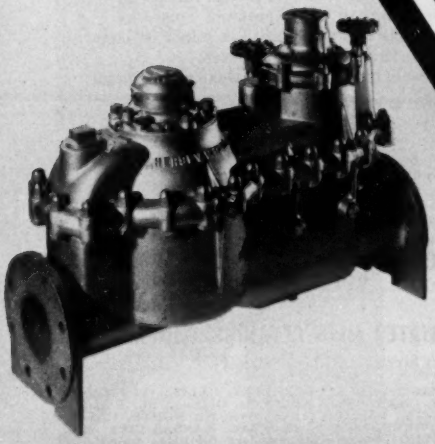

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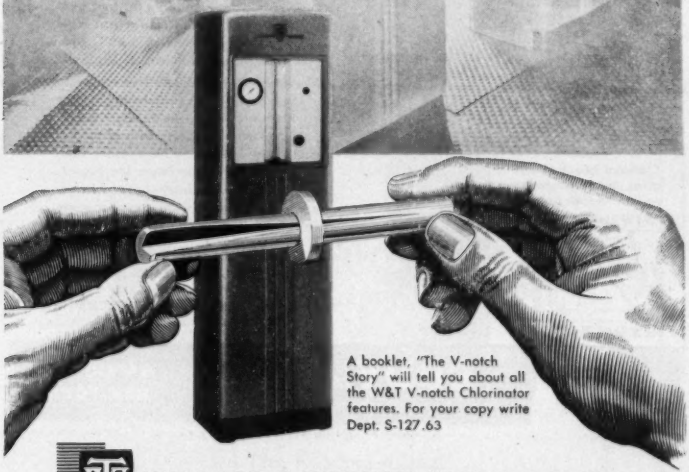

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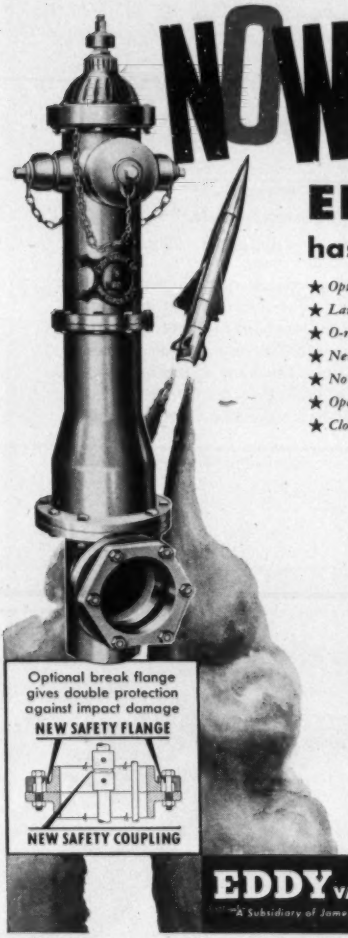

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- Bell Ends

FIG. 571X
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- Parallel Seats
- Mechanical Joint Ends

FIG. 561
- Inside Screw
- Non-Rising Stem
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FIG. 566
- Outside-Screw-and-Yoke
- Rising Stem
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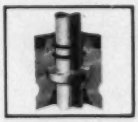

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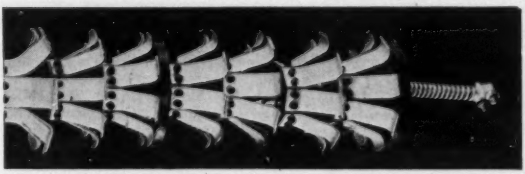

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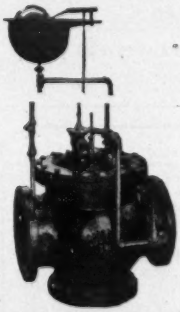

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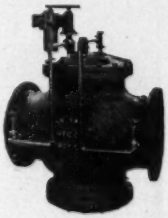

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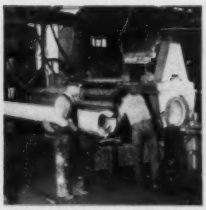

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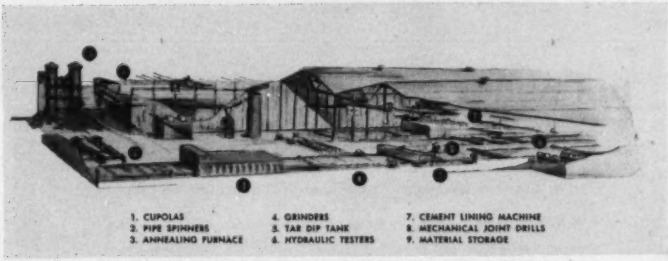


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